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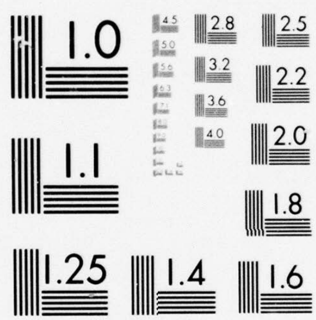

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TECHNICAL REPORT: NAVTRAEQUIPCEN IH-251

ACCEPTANCE TESTING OF FLYING QUALITIES AND PERFORMANCE, COCKPIT MOTION, AND VISUAL DISPLAY SYSTEM SIMULATION FOR FLIGHT SIMULATORS

Computer Laboratory
Naval Training Equipment Center
Orlando, Florida 32813

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An investigation of the techniques used by Government and industry in performing acceptance testing of flight simulators was conducted. Recommended specification languages are provided for testing three major areas of flight simulator systems; Flying Qualities and Performance simulation, Cockpit Motion simulation, and Visual Display simulation.

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SUMMARY

Today's flight simulators are being called upon to provide training in obtaining basic flight skills as well as the maintenance of flight skills and system operation proficiency by experienced aviators. In some cases, the acceptability of the flight simulators purchased by the U.S. Navy has been less than desired. This study addressed three areas of acceptance testing; in particular, flying qualities and performance, cockpit motion, and visual simulation. Proposed specification languages detailing tests to be performed, recommended procedures, test criteria and suggested tolerances are included as appendixes. These appendixes may be detached for independent use.

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SECTION I

INTRODUCTION

The Office of the Secretary of Defense has directed the services to strive to achieve a total flight hour reduction of approximately 25 percent by the end of FY 1981. This is to be accomplished through continued development of new training techniques and greater utilization of flight simulation. Before quantative substitution coefficients relating simulator "flight" time to operational aircraft flight time can be determined, techniques must be developed which can be used to certify a level of "fidelity" of simulation of a particular series of training devices.

Today's flight simulators utilizing visual display and cockpit motion systems are used to provide training for the teaching of techniques such as basic flying techniques, communication and navigation procedures and techniques, cockpit procedures, and weapons system operating techniques to new pilots and equipment operators and teaching advanced techniques such as carrier and field landing, airborne refueling, air to ground weapon delivery and air combat maneuvering, as well as maintaining proficiency in these areas.

The acceptability of these Weapon System Trainers (WST's) and Operational Flight Trainers (OFT's) by user pilots, has been at a level much lower than desired.[1] Prior to the introduction of visual display systems, the predominate criticisms of WST's and OFT's were in the areas of control feel, engine dynamics and cockpit motion cueing. The introduction of visual display systems added to the complexity of the training devices and added a new dimension of cue perception and in addition highlighted any errors in flying quality and performance (FQ&P) simulation which may have existed, but not previously noticed in simulators used as instrument trainers. In general, the number and severity of the existing criticisms were not reduced by the addition of the visual display systems but instead have been enlarged to include: stability and control problems such as Pilot Induced Oscillations (PIO) in the longitudinal, lateral and directional axes; airframe reactions due to changes in power and configuration; and difficulty in tracking tasks such as carrier landings (lineup and holding the "meatball"), formation flying, and weapons delivery. As an example of the difficulties which can be encountered in interfacing a visual display system

1. Mackie, Robert R.; Kelley, Gene R.; Moe, Gary L. and Mecherikoff, Michael. "Factors Leading to the Acceptance or Rejection of Training Devices," NAVTRAEQUIPCEN 70-C-0276-1, August 1972.

to a flight simulator, consider Device 2F90. From the time of its delivery in 1969, until September 1972, it was well received and provided effective transfer of training.[2]

After the introduction of a computer generated image visual display system, a host of problems became apparent.[3] In the case of Device 2F90, a team effort by personnel from the Chief of Naval Air Training (CNATRA), Training Wing Two (TRAWINGTWO), the Naval Air Test Center (NAVAIRTESTCEN), Naval Training Equipment Center (NAVTRAEQUIPCEN), Naval Education Training and Program Development Center (NAVEDTRAPRODCEN), and Naval Air Systems Command (NAVAIRSYSCOM) providing funding was successful in correcting the majority of problems encountered. The specific nature of the problems and their solutions are reported elsewhere.[4]

A large group of problems were due to a lack of fidelity in the simulation of the TA-4J flying qualities and performance (FQ&P). The simulation was sufficiently accurate for the instrument training and emergency procedures training but not when used for the visual tasks. Clearly, a methodology must be determined for performing acceptance testing which will aid in achieving user acceptance.

A logical question would follow--What is meant by the word acceptable? To the training specialist a device might be acceptable if a certain level of transfer of training is attainable; after all, training is the purpose of a training device. To the procuring activity a device delivered, on time, per the procurement specifications, and within contract costs might be acceptable. The user maintenance personnel feel easy maintenance and high reliability are key issues. Of course, the trainee wants to be trained in the actual weapon system rather than a simulator (with the exception of emergency procedures training which even pilots admit is more suitably performed in the simulators).

2. Ryan, L. E.; Puig, J. A.; Micheli, G. S.; and Clarke, J. C., "An Evaluation of the Training Effectiveness of Device 2F90, TA-4J Operational Flight Trainer: Part 1: The B-Stage," NAVTRAEQUIPCEN Technical Report IH-207.
3. O'Connor, F. E., CAPT USN; Shinn, B. J., Dr. and Bunker, W. M., Dr. "Prospects, Problems, and Performance - A Case Study of the First Pilot Trainer Using CGI Visuals", Proceedings of the Sixth Naval Training Equipment Center and Industry Conference, NAVTRAEQUIPCEN IH-226, Nov 13, 1973.
4. Harris, W. T., "Device 2F90 Flying Qualities and Performance Evaluation and Discrepancy Correction", NAVTRAEQUIPCEN Technical Report IH-245, September 1975.

The context of the word acceptable which will be addressed in this study is in reference to gaining trainee acceptance of the training device by improving the fidelity of the FQ&P through improved acceptance testing. This approach is taken because so little is known regarding requirements for fidelity of simulation as a function of training effectiveness requirements. How trainee acceptance of a WST or an OFT is to be gained is a function of the requirements to which the simulator was procured and the testing to which it was subjected. The analysis of the acceptance procedures is the problem area addressed by this study.

A statement of the intent of this study is in order. The intent of the study is to:

a. analyze the problems involved in simulator acceptance testing from an engineering point-of-view.

b. recommend a testing methodology which would reduce the problems.

c. point out areas of difficulty involved in using the recommended methodology.

SECTION II

BACKGROUND

When systems are as complex and expensive as modern WST's, it is not too surprising that the test program to which they must be subjected would also be quite complex. The Department of Defense requires that all training devices be procured using MIL-T-23991,[5] as a guide. Many examinations and tests to be applied to training devices are therein specified; these examinations and tests are shown in Tables 1 and 2.

This specification addresses general construction, workmanship and reliability of training devices but no detail is given as to what or how functional testing is to be performed. The U.S. Navy has seen fit to write another general specification MIL-T-82335,[6] which addresses the requirements for fixed-wing WST's and OFT's. This specification refers to MIL-T-23991 for all quality assurance provisions. The specification, last revised in 1969, is currently being expanded to include testing and rotary wing aircraft simulators. The U.S. Air Force has also written its aircraft trainer specification[7] which includes a rather detailed Quality Assurance Provisions section listing tests, test methods and conditions for evaluating some Computer, Flying Qualities and Performance, Engine Performance, Cockpit Motion and Visual Display tests. Table 3 lists the test categories called out in MIL-T-9212.

Navy Testing Experience

The Naval Training Equipment Center (NAVTRAEQUIPCEN) has had extensive experience in acceptance testing of WST's and OFT's. In the early years of simulator testing, a need was recognized for standardizing the procedures involved. As early as 1952, a specification[8] existed which detailed the testing of OFT's. The specification contained tests to be performed, test methods, variables to be recorded, test conditions, test configurations and tolerances to be met. Table 4 provides an outline of the test areas required by the Special Devices Center in 1952.

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5. Anon: MIL-T-23991, Military Specification - "Training Devices, Military; General specification for."
6. Anon: MIL-T-82335, Military Specification - "Trainer, Fixed-Wing, Flight; General Specification for."
7. Anon: MIL-T-9212, Military Specification - "Trainer, Flight Simulator, Aircraft, General Requirements for."
8. Anon: SDC 911-600, Department of the Navy Office of Naval Research - Special Devices Center, General Specification for Testing of Operational Flight Trainers and/or Tactics Trainer Simulation, 15 Aug 1952.

This specification remained in effect for several years. The testing program required by the specification was time consuming and aircraft had changed considerably since its introduction, hence, in the late 1950's the Naval Training Device Center (NAVTRADEVCEN), which superseded the Special Devices Center, contracted with the Cornell Aeronautical Laboratory to devise a testing methodology which would adequately test the OFT's and yet be much faster in implementation than the procedures of SDC 911-600. The results of the research appeared in a series of reports[9,10,11,12,13] directed toward the testing of analog computer equipped OFT's and WST's. Two important products of the research appeared in the first of these reports, NAVTRADEVCEN 318-1. Recommended revisions to NAVTRADEVCEN specification 911-600A were incorporated into another specification[14], NAVTRADEVCEN 31-610, which superseded SDC 911-600. The changes recommended were not extensive with regard to which variables and parameters were to be investigated. Another important product of Newell's research was a grouping of tests which could be performed simultaneously. However, this simultaneous data gathering required a considerable amount of engineering analytical talent was required to interpret correctly the results of the testing program. In NAVTRADEVCEN 318-1* Newell said "The traces should be analyzed by the engineering personnel who are familiar with both simulator design techniques and airplane response characteristics. A thorough knowledge of airplane dynamics, computers and transient and frequency response techniques should be prerequisites for the task of evaluating a flight simulator." This statement is as true today as it was in 1959.

9. Newell, Fredrick D.; NAVTRADEVCEN 318-1, Final Report "Dynamic Test Program for Weapons System Trainers", April 1959, (AD-228942), Unclassified.
10. Newell, Fredrick D.; Schelhorn, Arno E.; NAVTRADEVCEN 318-2, Final Report, Phase III: "Dynamic Test Program for Weapon System Trainers," March 1961, (AD-323180), Confidential.
11. Schelhorn, Arno E.; NAVTRADEVCEN 318-3, "Preliminary Design Report for NTEC Research Model Tech Equipment," February 1960, Unclassified.
12. Newell, Fredrick D.; Schelhorn, Arno E.; NAVTRADEVCEN 318-4, "Summary Report Phase IV: Dynamic Test Program for Weapon Systems Trainers," June 1961, (AD-262667), Unclassified.
13. Newell, Fredrick D.; Schelhorn, Arno E.; NAVTRADEVCEN 318-5, "Final Report Addendum: Application of Dynamic Test Techniques to Weapon System Trainers," September 1960, (AD-484396), Unclassified.
14. Anon: U.S. Naval Training Device Center 31-610, "General Specification for Functional Test Requirements - Fixed Wing Aircraft - Weapon System Trainers (Flight)", 30 August 1963.
* See Reference 9.

Table 5 details the primary areas currently relevant in simulator acceptance testing.

The areas of Maintainability, Reliability and Electromagnetic Interference are not included, because they are well defined and established by Military Standards.[15,16,17,18,19]

There are areas of testing shown on Table 5 which are also relatively well defined with respect to test methods and other than mentioning their existence will not be treated further herein. Such areas include: computer hardware diagnostics, which are supplied by the computer manufacturer; computer software requirements and system diagnostics are delineated in another military standard[20]; Navigational and tactical simulated systems, which are best tested by skilled operators evaluating the equipment; Instructor functions, Computer Aided Instruction and mission playback functions, tend to be best evaluated subjectively.

There are then three major areas of a simulation system evaluation process which need to be considered and which constitute the focus of this research effort. They are:

a. Flying Qualities and Performance (FQ&P) including engine performance.

b. Cockpit Motion (CM) systems.

c. Visual Display (VD) systems.

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15. Anon: MIL-STD-470, Military Standard; Maintainability Program Requirements (For Systems and Equipments).
16. Anon: MIL-STD-471, Military Standard; Maintainability Demonstration.
17. Anon: MIL-STD-781, Military Standard; Reliability Tests, Exponential Distribution.
18. Anon: MIL-STD-785, Military Standard; Requirements for Reliability Program (For Systems and Equipments).
19. Anon: MIL-STD-826, Military Standard; Electromagnetic Interference Test Requirements and Test Methods.
20. Anon: MIL-STD-876 (USAF), Military Standard; Digital Computation Systems for Real-time Training Simulators.

Simulation Fidelity Problems

There are several reasons why the simulation would not be of sufficient fidelity. These reasons are shown in Table 6. Most of these reasons appear to be easily noted a priori. However, in practice, they are often not recognized until acceptance testing has been conducted and hence constitute a major reason for performing acceptance testing.

Presently Utilized Methods of Training Simulator Testing

Commercial, Air Force, Army, Navy and Marine training flight simulator acceptance procedures were investigated in this study. Prior to 1974, the various users had been acceptance testing their training devices in a similar fashion. The simulator manufacturer recommended some tests of his simulator's FQ&P, CM and VD systems, as presented in some test document. These tests were reviewed and approved with changes deemed necessary by user acceptance personnel. The simulator was then tested to the approved test document. The next portion of the acceptance procedure usually involved a subjective evaluation by one or more experienced pilots who flew various tasks in the simulator and provided comments of discrepancies to the simulator manufacturer for corrective action. The corrective action was then re-evaluated by the pilots and the iterative process would continue. A level of acceptability would be attained and the simulator would be accepted. The proceeding testing can be presented as three stages:

a. Factory testing - Verifying that the simulator does what the acceptance procedure delineates the simulator to do.

b. On site testing - Verifying that the simulator still does what it did at the factory after the equipment has been shipped to the operational site.

c. Subjective evaluation of the FQ&P by user pilots.

The commercial users would continue the iterative process for some time (a year of additional engineering testing modification and development was not uncommon) until their key acceptance pilots were satisfied with the simulated FQ&P.

After 1974, the Navy and Marine Corps adopted a different procedure. The training simulators were accepted using test pilots from either the NAVAIRTESTCEN or from the manufacturer of the simulated aircraft (e.g., Lockheed test pilots were used to evaluate the P-3 simulators) to gather specific engineering FQ&P test data and comparing the simulators FQ&P test data to the actual aircraft FQ&P data. For the FQ&P testing, the

tests which were conducted and test methods used were those taught by the Navy at the U.S. Navy Test Pilot School (USNTPS). These test procedures are detailed in the textual material[21,22] used in that school's coursework. Similar techniques and theory are described by the U.S. Air Force in their test pilot manual[23].

The acceptance (or verification) testing procedure used by the Research and Engineering development simulator personnel to verify the FQ&P of a simulator are somewhat different than those usually found in training and commercial simulators.

Engineering simulators, as used in aircraft development are usually initially designed using wind tunnel and empirical data obtained prior to the aircraft's first flight and are modified using aircraft test data as it becomes available. The tests conducted to verify the FQ&P are of the type used by the Navy today, i.e., the standard measures taken during aircraft evaluation are repeated for the simulation and compared to the corresponding aircraft data.

There is some work being done in research directed towards automating the process of acceptance testing the FQ&P simulation of a training device. This line of research is being conducted by Goodyear Aerospace Corporation[24] and by the Air Force Human Resources Laboratory.

Cockpit motion and visual display systems are almost exclusively accepted using subjective evaluations. A notable exception to the above statement is a recent evaluation effort[24] (called Project 2235) performed by the US Air Force in which four state-of-the-art visual display system equipped simulators were evaluated for their effectiveness in providing training for the

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21. Langdon, S. D. LCDR USN, "Fixed Wing Stability and Control Theory and Flight Test Techniques" Naval Test Pilot School Flight Test Manual, USNTPS-FTM-No 103, Aug. 1969.
22. Small, S. M., LCDR USN and Prueher, J. W., "Fixed Wing Performance Theory and Flight Test Techniques," Naval Test Pilot School Flight Test Manual USNTPS-FTM-No 104, July 1972.
23. Anon: "Stability and Control", FTC-TIH-64-2004, USAF Aerospace Research Pilot's School Rev. Nov. 1964.
24. Jacobs, W. B.; "Automated Simulator Test and Checkout", Goodyear Engineering Report GER 16011, Jan. 1974. (Ref. IR & D Project No. 0509-73-D5). Proprietary.
25. Hutton, D. P.; Burks, D. K.; Englehart, J. D.; Wilson Jr., J. M.; Romaglia, F. J.; and Schneider, A. J.; "Final Report Project 2235 - Air-to-Ground Visual Simulation Demonstration" P.E. 64227F, October 1976.

conventional and tactical air-to-ground weapons delivery tasks. This evaluation effort consisted of two different types of evaluation. The first was a technical evaluation of the various display systems' capabilities in terms of engineering performance measures. The second type of evaluation was a subjective evaluation of how well each of the systems tested were able to provide the cues necessary for accomplishing the weapons delivery tasks. The technical evaluation phase is of particular interest in that four different types of systems were tested including Computer Generated Image (CGI) systems, Terrain Model Board (TMB) systems and combinations of the systems. The technical testing program of this project is summarized in Table 7. The test set-ups are shown in figure 1.

The types of technical tests chosen were well suited to the intended purpose. For example, The Modulation Transfer Function (MTF) provides information on the capability of the system to display detail; the photometer measurements provide an additional measure of scene detail, display capability and a measure of scene luminance; the distortion tests provide information on perspective errors, distortion and field of view. The observer camera technique used was developed, described, and verified by Harshbarger et al in the mid 1960's[26,27,28,29]. The technique provides a uniform method of comparison of various systems as long as a "standard" observer camera is used.

The U.S. Navy also is involved in the procurement of and testing of VD systems. Driskell provides[30], among other things, a specification language intended to serve as a guide in procuring of and acceptance testing of VD systems. Although slanted toward TMB Systems primarily, the recommended tests are also meaningful for Computer Generated Imaging (CGI) VD systems. The tests recommended are shown in Table 8.

26. Harshbarger, John H.; Gill, Arthur T.; "Development of Techniques for Evaluation of Visual Simulation Equipment", AMRL-TDR-64-49, August 1964.
27. Harshbarger, John H.; "Test and Evaluation of Electronic Image Generation and Projection Devices - Volume I - Evaluation Technique", AMRL-TR-65-116, Vol I, August 1965.
28. Harshbarger, John H.; Basinger, James D.; "Test and Evaluation of Electronic Image Generation and Projection Devices-Volume II-Evaluation of Television Systems", AMRL-TR-65-116, Vol II, November 1965.
29. Harshbarger, John H.; Basinger, James D.; "Test and Evaluation of Electronic Image Generation and Projection Devices - Volume III - Evaluation of Projection Screens", AMRL-TR-65-116, Vol III, December 1965.
30. Driskell, Carl R., "Capabilities in Wide Angle Visual Technology", NAVTRAEQUIPCEN IH-237, December 1974.

For more than thirty years, a search has continued for a universally recognized criterion of merit which may be used to objectively evaluate the image content of a display. Of course this area of endeavor is strongly related to the determination of an objective measure of display resolution. Lindenberg reported[31] that of the three most popular techniques for determining system resolution, the Modulation Transfer Function (MTF) is the most convenient primarily due to its advantages in obtaining a system MTF as the product of the component MTF's and in being able to determine the visual acuity limit of a system. Two investigations[32,33] report high correlations between the Modulation Transfer Function Area (MTFA), (defined as the area between the MTF curve and the visual threshold Modulation Curve), and both objectively measured information extraction and a subjective image quality rating.

Problems with the Presently Used Methods of Simulator Testing

Several problems exist with the methods of simulator acceptance testing in use today. Consider the objective portions of the testing programs, that is, the portion of the testing program in which specific measurements are made and compared to the test criteria provided by the simulator manufacturer or the procuring activity. The problem is in not using aircraft data as the criteria of merit for the acceptance testing. The fidelity assessment should determine how like the <u>aircraft</u> performance the simulated aircraft performance is. Current testing philosophy uses the engineering development simulation data and merely proves that the solutions of equations obtained on one computer are the same as those obtained on another.

31. Lindenberg, Klaus, "Objective Evaluation Method for Simulated Visual Scenes - Preliminary Analysis", NAVTRAEQUIPCEN TN-47, August 1976.
32. Borough, H. C.; Fallis, R. F.; Warnock, R. H.; and Britt, J. H.; "Quantitative Determination of Image Quality," Boeing Company Report D2-114058-1, May 1967.
33. Klingberg, C. S.; Elsworth, C. S.; and Fillean, C. R.; "Image Quality and Detection Performance of Military Photo Interpreters," Boeing Company Report D162-10323-1, September 1970.

Another set of objective problems appears with the observer camera technique used in obtaining the Modulation Transfer Function (MTF) of Visual Display systems. The first[34] limitation is that it requires a special camera of high sensitivity (since most visual display systems encountered in simulation have relatively low brightness) and a linear brightness response. The second limitation is that the technique is very awkward to use in making color display measurements. Another factor for consideration is the level of skill required by the test personnel for data taking and analysis. Finally, it can be difficult to locate the required instrumentation at the pilots eye point in the simulator.

The problems associated with the subjective evaluations are well known to personnel associated with acceptance testing and model construction. They include:

a. Accomodation - subjective appraisals of a simulation will vary as the evaluator becomes accustomed to the simulation being evaluated. This is especially noticeable when FQ&P characteristics are being evaluated. Interestingly, the better pilots accomodate even easier than less capable pilots and in short order "learn" to fly the simulator and thereby lose their objectivity.

b. Multiple subjective opinions of exactly the same simulation will indicate different degrees of fidelity of the simulation. Again, particularly in the evaluation of the control loading (force feel) system. This situation exists if the multiple subjective opinions are offered by the same evaluator at different times due to fatigue, accomodation, external stress situations (health, emotional stress, etc.) or for unknown reasons. This problem is further complicated if multiple subjective opinions are offered by multiple evaluators each performing multiple evaluations.

c. It is generally difficult to interpret, in engineering terms, the subjective opinions offered when corrective efforts are required, i.e., correcting some area of simulation provided by the mathematical model. Comments such as "The controls didn't feel right" are common.

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34. Ewart, Ronald B.; Harshbarger, John H.; "Measurement of Flight Simulator Visual System Performance," Journal of the Society of Photo-Optical Instrumentation Engineers (SPIE) Vol 59 (1975) Simulators and Simulation.

d. Not all areas of simulation are sufficiently toleranced in the procurement documents such as MIL-T-82335, MIL-T-9212, MIL-T-23991, but even the areas which are, present considerable difficulty in determining acceptability when the opinions offered are subjective. For example, an opinion might be that the fuel flow is too high at .8 Mach and 35,000 feet altitude. The fuel flow is allowed to be somewhat in error, as defined by the tolerances, and an objective measurement is required to ascertain whether the simulation is within tolerance.

Another problem area is in the testing of cockpit motion and visual display systems. These systems have been acceptance tested primarily using subjective evaluations rather than objective measures. This constitutes a problem area because the newer procurement specifications cite cockpit motion and visual display system requirements in terms of engineering performance measures. These performance measures must be verified to determine the satisfaction of contractual obligations. The testing of these engineering performance measures should be objective, treating the systems to be tested as servo-mechanisms and subjecting them to the usual "servo" type performance testing such as static and dynamic performance and interface performance. The cueing delivered by a cockpit motion system should be tested both objectively and subjectively. This requirement is made manifest because the cue delivered by a cockpit motion system is a function of both the hardware capability and the manner the platform is driven. Since there is no universally recognized drive algorithm (and associated gains and frequencies) there is no such concept as the "correctness" of the cues provided. In fact, there is some controversy as to exactly what constitutes a cue. Hence a subjective appraisal is still required.

The objective measurements are necessary to verify that smoothness, cue synchronization and orientation are within tolerances. Subjective appraisals are necessary to evaluate the effects of such accelerations as those caused by buffets, stalls and spins.

Finally, the task of procuring flight simulators for use by the Fleet is complicated by several factors. These factors comprise several general areas including:

a. The current test procedures used do not necessarily have anything to do with gaining or insuring acceptance by the user Fleet pilots.

b. The current test procedures do not adequately test a training simulator. In particular, the areas of ground and airborne handling, engine, cockpit motion and visual simulation are insufficiently tested.

c. The Fleet Project Team (FPT) is not satisfied with the current acceptance testing procedures.

d. Exactly when should the flight simulator be purchased: If purchased prior to the construction of the aircraft, insufficient data exists to build or test the simulator. If the simulator is procured after fleet introduction, the squadrons have no tool to train the pilots on until several years after they have the operational aircraft.

e. The personnel assigned to the FPT change, often during a simulator procurement.

f. There is some question as to exactly which documents should be used as acceptance criteria.

SECTION III

STATEMENT OF THE PROBLEM

The problem addressed by this report is that of defining a testing methodology which will assess the fidelity of FQ&P, cockpit motion, and visual display simulation in terms of engineering performance measures. The methodology should:

a. Be as free of the problems associated with the currently used methods as possible.

b. Be repeatable.

c. Have sufficient aircraft reference data available or obtainable.

d. Lead to greater pilot acceptance of the device when the test criteria have been met.

e. Be easily implemented.

f. Be uniformly applicable for all types of fixed wing simulators.

g. Recognize the tolerances encountered in aircraft coefficient data, performance data and in simulation computing inaccuracies.

h. Lead to a fidelity assessment which is of sufficient quality as to "certify" that the simulation provides the same FQ&P measures (within tolerance limits) as the operational aircraft.

Since the ultimate application of the recommended testing methodology is that of aiding in the procurement process in general, and acceptance testing of training simulators in particular, the methods developed must be stated in a form suitable for incorporation in a trainer specification.

SECTION IV

DISCUSSION

The emphasis of this effort was placed on satisfying the often mentioned areas of user complaint such as:

a. Handling qualities ("The trainer doesn't feel right")

b. Engine simulation

c. Areas which cause mission nonperformance - such as pilot induced oscillations or stable instrument trainers which are not "flyable" when mated to visual display systems.

d. Cockpit motion simulation

These problem areas were addressed by first identifying the characteristics which distinguish an aircraft to the pilot. That is, identify what a pilot perceives, while operating an aircraft, that indicates to him that he is flying a specific aircraft. These areas turned out to be those parameters detected at the man-machine interface. This interface includes such areas as:

a. Visually observable indications

b. Control feel - displacements, rates and forces

c. Acceleration cueing - cockpit motion systems.

d. Visual display systems

The approach taken to provide the required testing methodology was straight forward. The interface between man and machine was chosen as the focus of the testing effort. The testing effort was directed toward testing those areas of the simulation with which the pilot is subconsciously or consciously aware. Control loading (force, feel and deflection), power lever deflection and aircraft dynamics are areas that tend to be noticed at the subconscious awareness level. Aircraft trim settings, pitch angle, angle of attack and instrument indications in general tend to be noticed at the conscious awareness level.

The problem acceptance personnel encounter is to determine acceptance techniques which will allow a rapid assessment of those characteristics that distinguish an aircraft to the pilot. It is not sufficient to verify that a simulator performs as described by the mathematical model. The overall simulation system including simulated control feel, flying qualities and performance, cockpit motion and visual systems must be tested for compliance with the actual aircraft characteristics.

SECTION V

RESULTS

The products of this research appear as a collection of appendixes to this report. They are written in the general format of a specification and are numbered individually so as to be separately removable for use by various testing and procurement personnel.

Appendix A deals with the testing of the fidelity of Flying Qualities (handling qualities) and performance and engine performance. In particular, the categories shown in Table 9 are discussed in Appendix A. For each of these categories, test methods, conditions, equipment and configurations are recommended. The contents of Appendix A are being incorporated into the revision of MIL-T-82335 to be known as MIL-T-92032.

Appendix B deals specifically with testing of cockpit motion systems. Areas of testing recommended are shown in Table 10.

The contents of Appendix B are currently planned for introduction in a MIL STD for cockpit motion systems.

Appendix C treats the testing of visual display systems. Areas of testing discussed are denoted in Table 11.

In general the testing program that has been recommended in the appendixes employs a testing methodology which addresses end-product performance. For example, rate of climb testing indirectly verifies lift, drag, angle of attack, flight path angle, airspeed, altitude, gross weight and thrust calculations using as a criterion of merit a published measure of aircraft performance. This type of testing is well suited for performing acceptance testing but obviously is not the kind of testing methodology one would employ to determine the exact nature of a problem encountered when the rate of climb criterion has not been properly simulated. The "trouble shooting" type of testing involves careful engineering measurements of the many variables responsible for the calculation of the rate of climb. The data for these tests is often comprised of wind tunnel and engineering estimates, and hence may be suspect, furthermore, the implementation of the mathematical model or the mathematical model itself might be in error.

Sequencing of Testing

The specific ordering of tests shown in the appendixes is that of convenience. It is merely a grouping of tests by area of test and static or dynamic type of testing. Obviously there is no single optimum technique for collectively performing the testing. Considering the testing of FQ&P, it does appear that the testing is more readily accomplished by separating it into several general categories such as longitudinal, lateral-directional and portions of the performance with portions of engine performance constituting the final category. It also appears that an inverse relationship exists between the amount of combining of static and dynamic testing which can be performed and the level of knowledge of the engineering test personnel in the areas of aerodynamics, computer simulation techniques, transient and frequency response, and analytical techniques. That is, the more information which is to be extracted from the smallest amount of recorded data and control inputs requires more and more post-simulator-test data analysis. Hence a sensible trade-off must be made which considers level of skill of testing personnel, cost of testing time (including post test data analysis), and the nature and format of the aircraft data which is to be used as acceptance test criteria. Given that some such selection can be made, one such "optimum" sequencing of tests for the FQ&P testing was reported by Newell in NAVTRADEVCEN 318-1*. The published sequencing is still as good as any for the testing of portions of the performance envelope; certain cockpit motion and visual display system and added engine testing can be combined with the FQ&P testing. Table 12 summarizes this optimum sequencing of tests as updated for digital simulations, cockpit motion and visual display system dynamic testing. Notice that Table 12 is quite optimum with regard to establishing the effectiveness of the digital computer solution of a specific mathematical model; however, the transition phases of a mission such as take-off, landing, ground handling, buffet, etc. are not verified. Further notice that it is necessary to utilize the services of an experienced test pilot to draw the final comparisons to actual aircraft performance. The tests as outlined in Table 12 represent a maximum effort in dynamic testing leading to the minimum of actual simulator utilization time for testing. The amount of time spent in reducing the data and the chance of error in the data reduction are considerable. In the comparison of overall simulator testing and data reduction, the groupings, as set forth in the appendixes using computerized data recording and test aids such as Mach and altitude hold and auto trim, are more direct, easier to conduct and faster than the maximum dynamic test effort.

* See Reference 9.

Simulation Tolerances

The problem usually encountered in simulator procurement and acceptance testing is not to troubleshoot an existing simulation but rather to determine the satisfaction of contractual obligations involving levels of simulation fidelity as detailed in some specification. Before any determination of satisfaction of contractual obligation can be accomplished, exactly what is being simulated, what variables are being simulated, to what level of accuracy or within what tolerance band the simulation is acceptable must be stated in the contractual documentation. An overview of the specifications (MIL-T-23991, MIL-T-82335, MIL-T-9212, etc.) used in simulator procurement by the Military revealed that many of the variables felt required to be specified by this research were not toleranced in any fashion. Others were toleranced but in an awkward fashion. Hence, a set of recommended FQ&P tolerances are compared in Table 13 to those published in the various simulation specifications and testing documents in recent use by the Armed Services. The tolerances which are recommended are based on an engineering evaluation of aerodynamic coefficient data scatter, accuracy of test methods, and simulation and modeling accuracies available today.

Primarily three publications contained the tolerancing information available on cockpit motion simulation. MIL-T-82335 and MIL-T-9212, the Navy and Air Force General Specification for Flight Simulators and MIL-STD 1558[35], a standard dealing with the requirements of six-degree-of-freedom cockpit motion systems. Table 14 contains the published CM tolerances and the recommended tolerances to be used when published tolerances are not found in the detail specifications used in the simulator procurement.

The testing of cockpit motion systems is complicated by the fact that there is no universally recognized CM drive philosophy. This means that the motion platforms are commanded to do different things depending on the particular drive philosophy chosen. As a result, the testing philosophy recommended is one that tests the hardware, as a servo system, using standard static and dynamic tests. The cueing provided by the motion simulation is evaluated in terms of: verifying the washout rates; verifying the synchronization of the various systems being commonly driven, e.g., visual display, cockpit indicators, g-seat, g-suit, etc.;

35. MIL-STD-1558, Military Standard - "Six Degree-of-Freedom Motion System Requirements for Aircrewmembers Training Simulators" 22 February 1974.

verifying how well the simulated cockpit motion acceleration tracks the "ideal" acceleration provided by the equations of motion and finally verifying the interaction of the cockpit motion hardware and the remaining simulation capabilities such as freeze, reset, etc. Tolerances are suggested for the hardware attributes, washout rates, cueing orientation and synchronization. While comparisons can be made between motion cueing provided and the theoretically "ideal" motion, no tolerances can be recommended for the actually delivered cueing since it is restricted to hardware and software drive philosophy capabilities. Tolerances can be and are recommended for the timing of the cueing and the rates of washout. Never-the-less the comparisons between delivered cockpit motion accelerations and the "ideal" motions can and should be made a part of the acceptance testing procedures.

Visual display system testing is complicated because it is a new area of simulation and in general is loosely specified in the procurement documentation. Very little tolerance information is available in the general military standards. Table 15 contains the published tolerances of MIL-T-9212 and the recommended tolerances for testing total end-to-end system performance as well as sub-system performance.

Data Problems

No testing philosophy can be of value unless there exists a well-defined, readily obtained reference criterion. In the three categories of testing considered by this study, there exist several areas in which reference data are not normally available. The tests, conditions, configurations and data required for aircraft testing are presented in MIL-D-8708[36] and in the detail specifications used in the procurement of aircraft. As thorough as this document is for aircraft testing, still more data is required for simulator testing. Areas of particular importance include: longitudinal, lateral and directional responses due to small control inputs (± 1/2 inch); power plant responses due to small (± 1/2 inch) excursions of the power level angle (for approach testing about the "on speed" setting) and ground handling data. It is important to note the differences in intent between the two types of testing. One, normal aircraft testing, is intended to determine the safety of and suitability of the aircraft to perform its intended role in the Fleet. The other, simulator testing, is intended to ascertain how much like the operational aircraft the simulator performs.

36. Anon: MIL-D-8708, Military Specification; Demonstration Requirements for Airplanes.

Table 13 denotes the data not normally available in FQ&P and engine performance testing. These data can be obtained but are not currently required in a flight testing program. Another problem is that the actual aircraft FQ&P data is not always available in the normally encountered operational performance envelope. Rather, it is usually published for the outer edges of the performance envelope such as limiting center of gravity, overloaded gross weight or using trial control systems and the like. There is no reason it could not be available since the normal operational envelope is first established and then extended to the limiting envelope via the aircraft testing process. Recognize that two distinct kinds of aircraft data are required to obtain and validate the simulation of an operational aircraft. The first type is the coefficient data used to form the forcing functions of the differential equations of motion. This data is usually known as stability derivations, aerodynamic derivatives or aerodynamic coefficients. These data are required to build the simulation of a specific aircraft and in fact are the parameters that distinguish one aircraft's FQ&P from another. The data are usually obtained from wind tunnel experimental work with some occasional flight data reduction data. There exist several new, still experimental, computer algorithms for extracting the aerodynamic derivatives from actual recorded aircraft FQ&P data.[37] The National Aeronautics and Space Administration (NASA), NAVAIRTESTCEN and the Naval Air Development Center all are active in this attempt at extracting aerodynamic derivative data from FQ&P test data. The FQ&P test data (or flight test data) referred to is the second general type of data required and is needed to actually compare the resultant simulation to the aircraft which is represented.

In cockpit motion system and visual display system testing the criteria of merit must generally be established in the procurement specifications. That is, in order to determine acceptability of a CM system, its performance measures must be stated and then tested against using some appropriate tolerancing information. The specified performance measures would ideally be based on engineering/economic/human factors/training analysis type inputs citing variable requirements such as, for example, excursion limits, as a function of training requirements tempered with engineering capability and economic realities. In any case, the current state-of-the-art allows only the "mechanical" performance characteristics of the CM on VD system to be specified and tested against. We do not know which CM drive philosophy is "best" nor do we know what is required from the CM system with respect to jerk, acceleration, velocity cueing philosophy or washout algorithm choice with respect to training effectiveness.

37. Grove, Randall D., and Mayhew, Stanley C., "A Real-time Digital Program for Estimating Aircraft Stability and Control Parameters from Flight Test Data by Using the Maximum Likelihood Method," NASA TMX-2788, December 1973.

SECTION VI

CONCLUSIONS

Several conclusions were made during this task. They are:

a. A methodology exists for assessing the fidelity of the Flying Qualities and Performance simulation. It is based upon measures that are discernible to the pilot at the conscious or subconscious levels of awareness and compares simulator performance to aircraft performance.

b. A methodology exists for testing cockpit motion systems with respect to mechanical performance characteristics.

c. Cockpit motion cueing delivered by the motion platform is a function of the choice of drive philosophy algorithm chosen and hardware capability. Hence, unless a particular drive algorithm, gains, scaling, etc., can be stated a priori, only subjective appraisals can be used to determine acceptability of the delivered cueing.

d. Visual display technology is relatively new; however, engineering testing can be performed at the system and sub-system level. Several industrial and commercial practices are available for determining television sub-system performance.

e. It is possible to "certify" the Flying Qualities and performance simulation to be as per the equivalent aircraft criteria within tolerances.

f. The ultimate goal for all simulators is to train; however, no relationships are published which relate training effectiveness and:

(1) Flying Quality and Performance simulation fidelity.

(2) Cockpit motion performance measures such as:

(a) Linear and Angular excursions

(b) Linear and Angular velocities

(c) Linear and Angular accelerations

(d) Drive philosophies (jerk, acceleration, velocity or positional matching)

(e) Washout algorithms

(3) Visual display system performance measures (resolution, contrast, information content, etc.)

Hence, the acceptance testing cannot be based upon training effectiveness requirements.

g. No simulation tolerances exist with respect to training effectiveness. The tolerances recommended in this study are based upon judgments of engineering feasibility tempered with economic viability.

h. There are currently areas of FQ&P data which are obtainable but not normally collected in aircraft testing. These areas are required and must be acquired to adequately evaluate the engineering performance of simulations.

i. In determining acceptability of engineering performance of cockpit motion and visual display systems, desired values of the various performance measures along with tolerances must be stated in the relevant procurement documents.

j. There is a strong tendency encountered in the testing of complex systems to measure a variable or parameter simply because it can be measured. A concerted effort must be made to not measure some of the classical variables of flight simulation (e.g., lift, drag, etc.) in favor of more inclusive measures (acceleration, deceleration, etc.). Acceptance testing is not to be confused with "trouble-shooting" testing in which the intermediate variables are of paramount importance. In cockpit motion and visual display system testing sub-system testing must be performed because few over-all performance standards can be established.

k. The "flight" test data requirements for simulator testing are in many ways more restrictive than for actual aircraft testing. For example, areas such as wheel brake effectiveness in aircraft is somewhat subjectively evaluated as "stops safely in required number of feet." The simulator must match the brake deflections and forces as well as the rate of turn per differential brake application (within established tolerances). Visual display system performance capabilities increase the data requirements and tolerances.

l. MIL-D-8708 would represent a suitable forum for stating the engineering test data requirements for use in simulator testing as well as for its original purpose.

SECTION VII

RECOMMENDATIONS

It is recommended that:

a. The relationships between training effectiveness and:

(1) Flying Quality and Performance simulation fidelity

(2) Cockpit motion performance measures - linear and angular excursion, velocity and acceleration; drive philosophy, etc.

(3) Visual display system performance measures

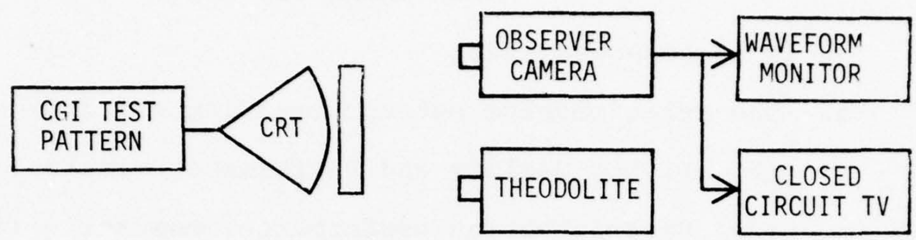
be investigated in order to establish testing requirements, simulation requirements and tolerances in terms of training needs.

b. The Flying Qualities and Performance measures and simulation tolerances be established for rotary wing aircraft.

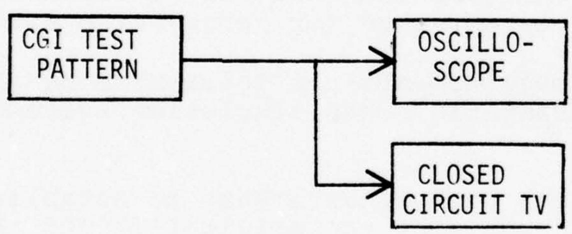
c. Performance requirements and tolerances be specified in the procurement documentation when simulation systems are to be purchased.

d. The flight test data requirements be established in some "normalized" fashion such that the original flight test work and the simulator "flight" test work could proceed simultaneously. This normalization would be based upon defined but indeterminant (a function of specific aircraft) values such as, for example, maximum velocity minus minimum velocity divided by some value and added to the minimum velocity. MIL-D-8708 cites somewhat normalized testing conditions such as "at least stall speed (landing configuration) plus 20" and would serve as a useful guide.

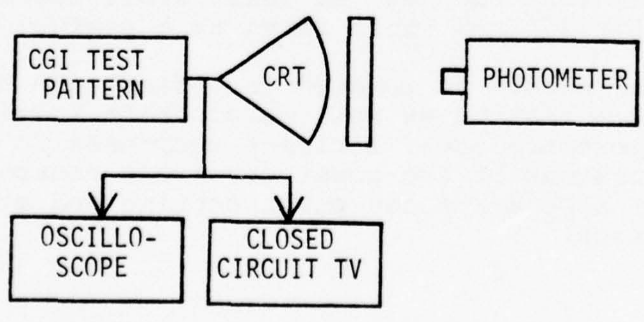
e. MIL-D-8708 should be updated to reflect the data requirements for simulator testing as well as aircraft testing. Areas of particular importance are: airframe responses to small ($\pm$ 1/2 inch) excursions of the power lever and control device about the optimum approach speed power setting and ground handling characteristics.



TEST SETUP A

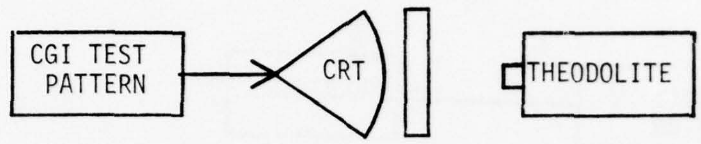


TEST SETUP B



TEST SETUP C

FIGURE 1. Visual System Test Configurations.



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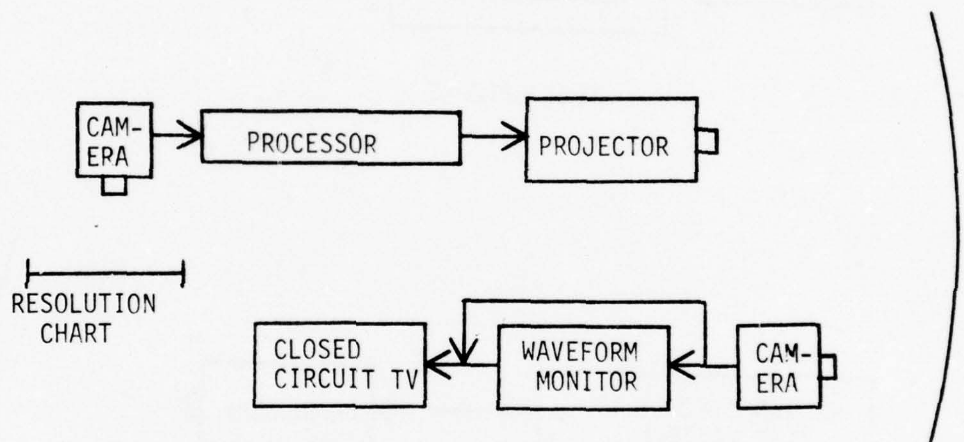


TEST SETUP E

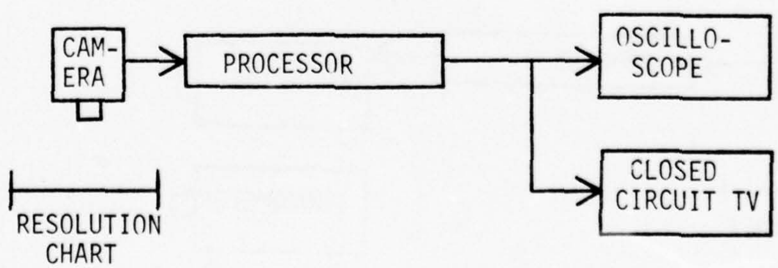


FIGURE 1.(Continued) Visual System Test Configurations.

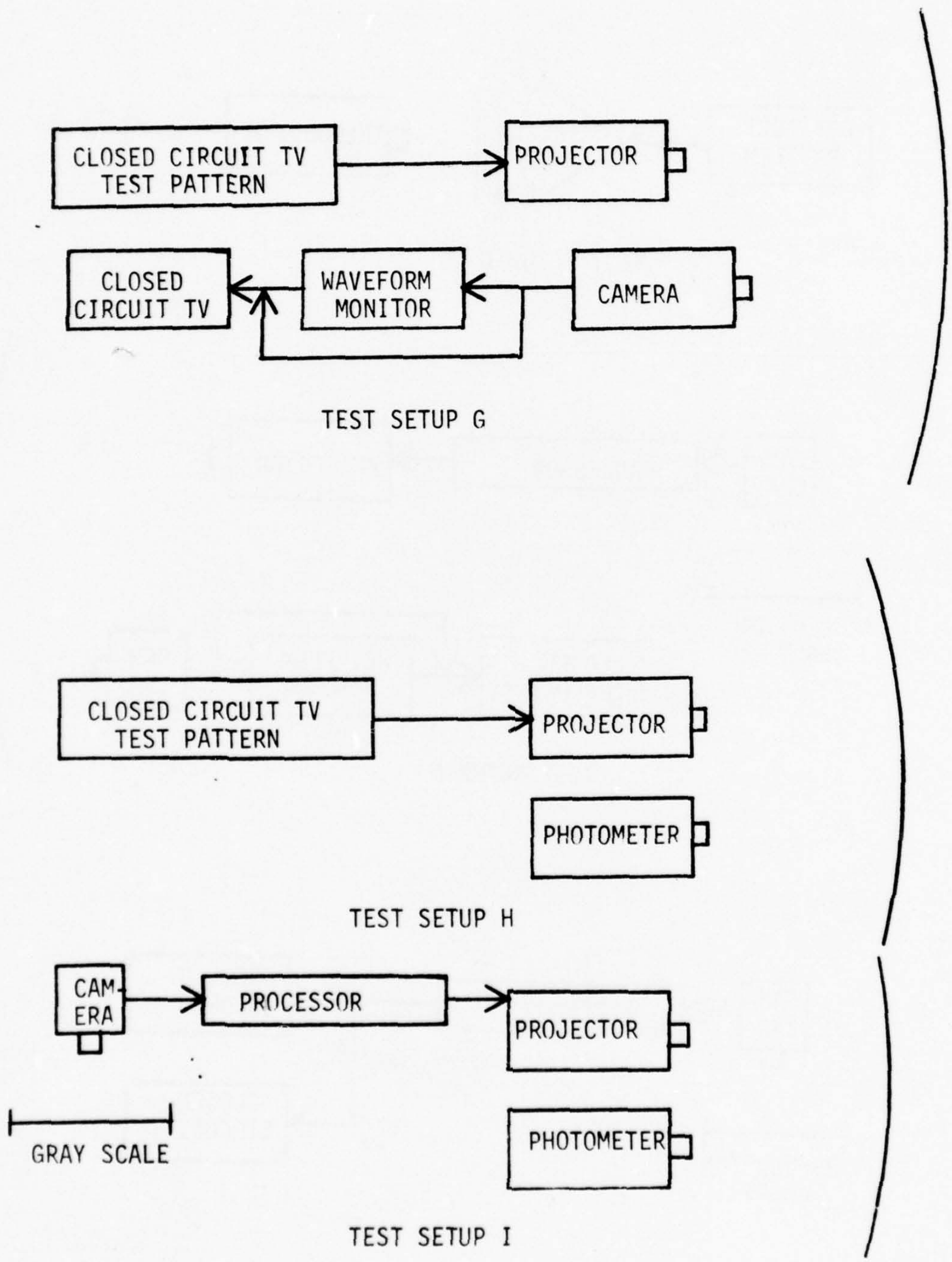
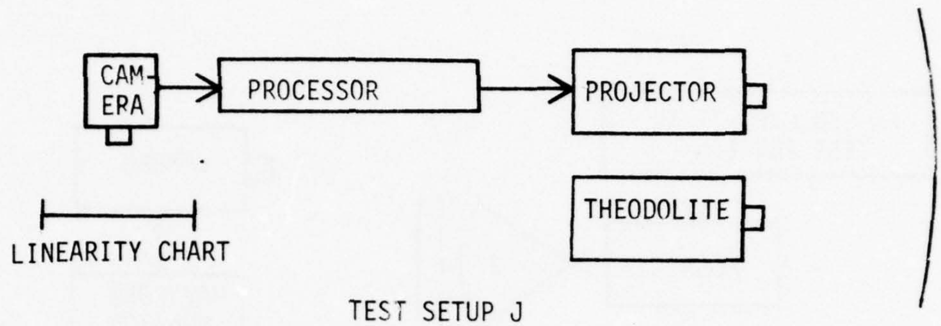
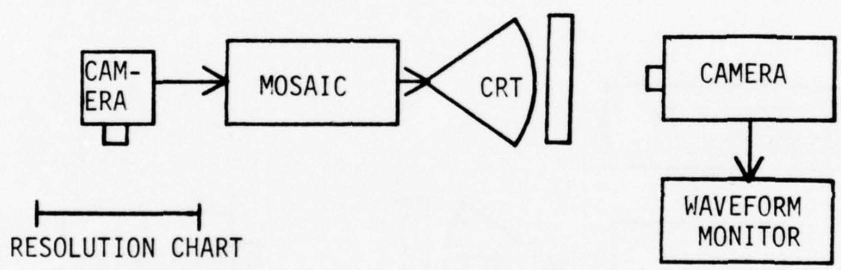


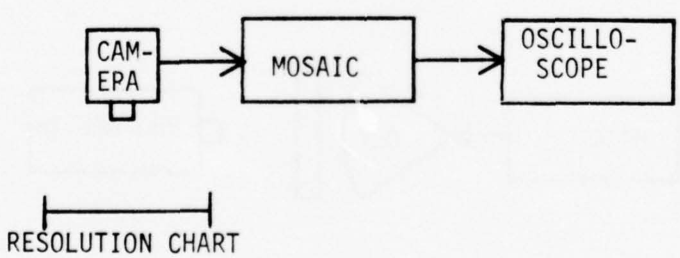
FIGURE 1. (Continued) Visual System Test Configurations.



TEST SETUP J

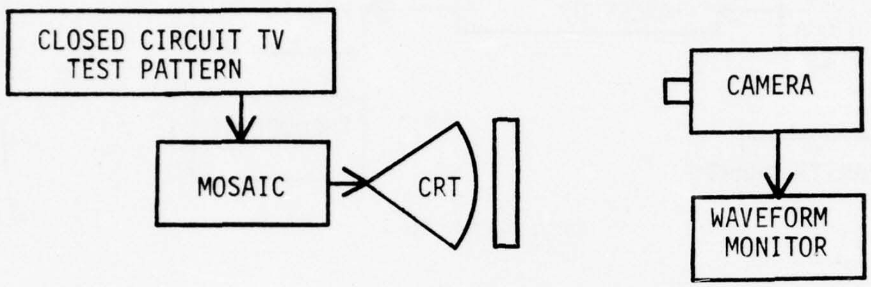


TEST SETUP K

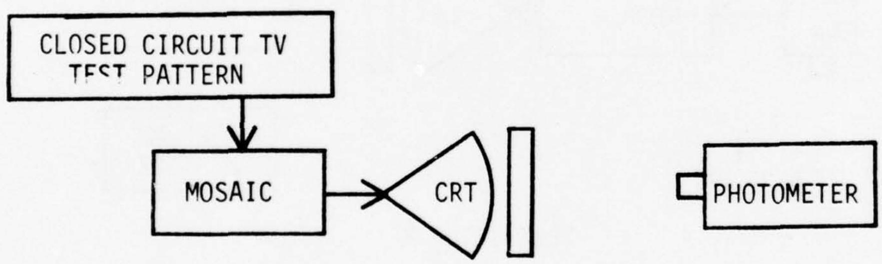


TEST SETUP L

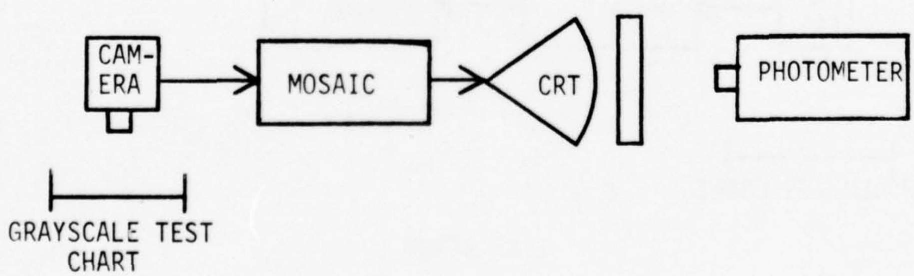
FIGURE 1. (Continued) Visual System Test Configurations.



TEST SETUP M

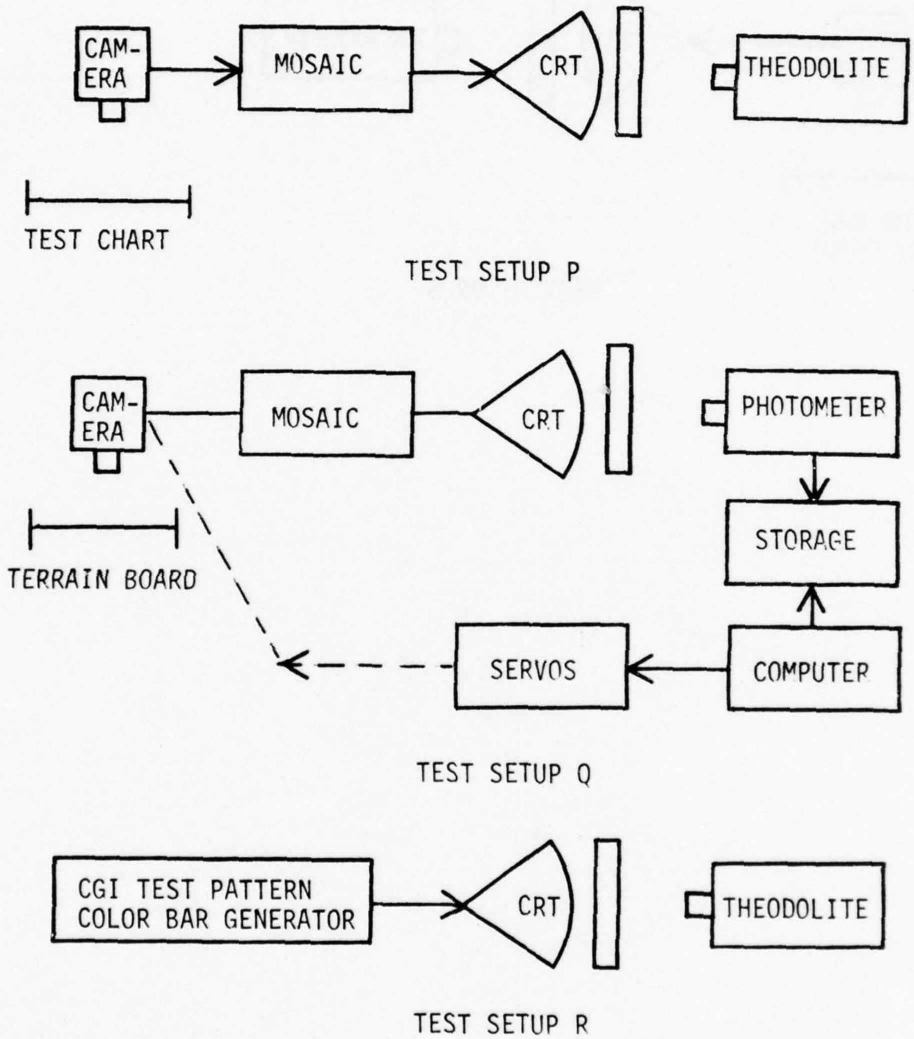


TEST SETUP N



TEST SETUP O

FIGURE 1. (Continued) Visual System Test Configurations.



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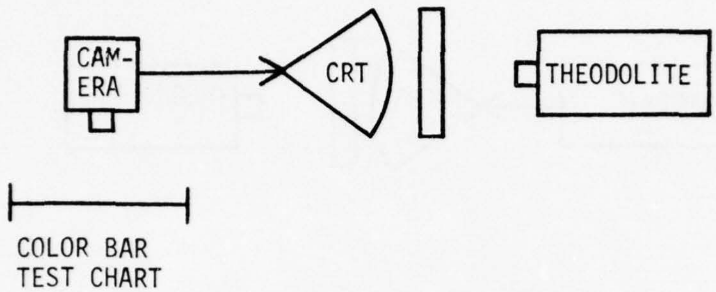

TEST SETUP S

FIGURE 1. (Continued) Visual System Test Configurations.

TABLE 1. MIL-T-23991 TRAINING DEVICE EXAMINATIONS

Materials

Parts (standard/nonstandard)

Design

Construction processes

Assembly and fit

Wire markings

Dimensions and tolerances

Size and weight

Color

Finish (corrosion protection and treatment)

Nameplates and product markings

Safety

Workmanship

TABLE 2. MIL-T-23991 TRAINING DEVICE TESTS

Functional

Trainer operation

Structural

Electrical

Grounding and grounding systems

Human Factors Engineering compliance

Reliability

Environmental

Electromagnetic interference suppression

TABLE 3. MIL-T-9212(USAF)-TRAINING DEVICE TESTS

Aerodynamic cross-coupling
Aerodynamic drag
Aircraft systems
Cargo extraction
Contractor-prepared test outline
Control force vs control deflection
  Actuator response
  Control friction and inertia
  Trim response
Dynamic stability:
  Low frequency gain
  Spiral stability
  Transient response
Electrical power input
Electromagnetic interference
Engine:
  Idle governing speed
  Oil pressure
  Oil temperature
  Rates
  Speed
  Thrust
  Windmilling
Examination of product
Exhaust gas temperature
Forward speed:
  Acceleration and deceleration
Fuel flow rate
Fuel depletion
Fuel pressure
Ground steering
Human engineering/performance
Inertia cross coupling
Mach no. vs true airspeed
Maintainability demonstration:
  Maintenance manuals and observations
  Maintenance task time
  Maintainability test methods
Materials and processes
Max speed indicator
Motion systems tests:
  Displacement of flight compartment motion
  Limits of motion
  Platform response
Navigation
Normal operation
Pitch control on ground
Power calibration
Power plant controls schedule

TABLE 3. MIL-T-9212(USAF)-TRAINING DEVICE TESTS (Continued)

- Pressure ratio
- Reliability demonstration and test:
  - Adjustments
  - Failure recording
  - Preventive maintenance during test
- Reliability sampling and longevity tests
  - Test plan
- Repeater instruments
- Servos
- Stalls and buffet
- Stopping time
- Surface deflection vs constant pitch rate:
  - Pitch acceleration
- Surface deflection vs constant roll rate:
  - Roll acceleration
- Surface deflection vs control deflection
- Surface reflection vs yaw rate:
  - Yaw acceleration
- Takeoff
- True airspeed vs indicated airspeed
- Turbine air temperature
- Ventilation
- Vertical Speed:
  - Vertical acceleration and deceleration
- Visual simulation system:
  - Geometric distortion
  - Image quality
  - Display contrast

TABLE 4. SDC 911-600 TRAINING DEVICE EXAMINATIONS

a. Control System Function

b. Performance
  (1) Stall and Approach Speeds
  (2) Takeoff
  (3) Climb
  (4) Level Flight
  (5) Performance at Altitude
  (6) Engine Characteristics
  (7) Fuel Consumption
  (8) Engine-out Performance
  (9) Acceleration Performance
  (10) Deceleration Performance
  (11) Descent Performance

c. Longitudinal Stability and Control
  (1) Dynamic Longitudinal Stability
    (a) Short Period Oscillation
    (b) Phugoid Oscillation
  (2) Static Longitudinal Stability
    (a) Elevator Control Effectiveness
    (b) Elevator Control Forces
  (3) High Speed Requirements
    (a) High Speed Warning
    (b) Control Forces in a Dive
  (4) Longitudinal Trim Changes
  (5) Longitudinal Trimming Devices

d. Directional Stability and Control
  (1) Dynamic Directional Stability
    (a) Lateral-Directional Oscillation
    (b) Short Period Rudder Oscillation
    (c) Spiral Stability
  (2) Static Directional Stability
    (a) Steady Yaw
    (b) Rudder-fixed Terms
    (c) Rudder-free Asymmetric Thrust
  (3) Rudder Control Effectiveness
    (a) Taxiing
    (b) Asymmetric Thrust
    (c) Adverse Yaw
  (4) High Speed Requirements
  (5) Directional Trimming Devices

e. Lateral Stability and Control
  (1) Dynamic Lateral Stability
    (a) Lateral-Directional Oscillation
    (b) Dihedral Effect
    (c) Criterion Control Effectiveness

TABLE 4. SDC 911-600 TRAINING DEVICE EXAMINATIONS (Continued)

(2) High Speed Requirements
(3) Lateral Trimming Device
(4) Stalling Characteristics

g. Power Operated and Power Boost Control System
(1) Control Force with Power Control System
(2) Emergency Requirements, Power Control System Inoperative
(a) Elevator
(b) Rudder
(c) Aileron
(3) Rolling Velocity
(4) Multiple Power Control Systems

h. Design of Control Loading System

i. Aircraft Systems
(1) Electrical
(2) Hydraulic and/or Pneumatic
(3) Power Plant
(4) Fuel
(5) Oil
(6) Oxygen
(7) Pressurization
(8) Heating and Ventilation
(9) Electronic Equipment
(10) Armament
(11) Radio Aids Installation

j. Aircraft Instrument Calibration
(1) Altimeter
(2) Compass
(3) Airspeed
(4) Rate of Climb
(5) Gyro Horizon

TABLE 5. SIMULATION SYSTEM TESTING AREAS

COMPUTER		
HARDWARE	SOFTWARE	INSTRUCTOR FUNCTIONS
1. CPU	1. Cycle Time Measurement	1. Displays
2. Memory	2. Simulation	2. Freeze
3. I/O	3. Debugging/Verification	3. Crash
a. Real time	4. Maintenance	4. Initial Conditions Reset
b. Discrete	a. Computer Diagnostic	5. Variable Insertion/ Display
c. Analog	b. Calibration	6. Playback
4. Peripheral	c. Daily Readiness	7. Ambient Conditions
a. Card Reader	d. Test Exercises	8. Turbulent Air
b. Line Printer	5. Utility	9. Simulation Operation
c. Typewriter	a. Assembler	10. Emergency Conditions
d. Tape Units	b. Loader	11. Malfunctions
5. Equipment Cooling	c. Conversion	12. Communications
	d. Printout	13. Navigation Aid Insertion
	e. Data Reduction	14. Computer Aided Instruction
	f. Output	

TABLE 5. SIMULATION SYSTEM TESTING AREAS (Continued)

SIMULATED SYSTEMS

AIRCRAFT	ENGINE	COMMUNICATION/ NAVIGATION	RADAR	WEAPONS
1. Landing Gear	1. Starting	1. TACAN	1. Fire Control	1. Armament
2. Wing Flaps	2. Statics	2. UHF	2. Navigation	2. Missile
3. Lighting	3. Dynamics	3. VHF	3. Search	3. ASW
4. Pneumatic	4. Controls	4. Nav Computer	4. BITS	4. ECM
5. Hydraulic	5. Performance and starting envelopes	5. Doppler	5. IFF/SEF	5. ECCM
6. Cockpit Heating		6. Inertial	6. Terrain Following	6. Special
7. Air Conditioning		7. Radio Direction Finding	7. Terrain Avoidance	
8. Caution/Warning		8. Loran		
9. Auto Pilot		9. Localizer		
10. Automatic Power Compensation		10. VASI		
11. Fuel		11. FLOLS		
12. Electrical		12. Compass		
13. Oil		13. Intercommunications		
14. Control Loading		14. Altimeters		
15. Trim				
16. Instruments/Indicators				
17. Heads-Up Display				
18. Nose Gear Steering				
19. Brakes				
20. Cabin Pressurization				
21. Anti-ice				
22. Oxygen				
23. Weight and Balance				

TABLE 5. SIMULATION SYSTEM TESTING AREAS (Continued)

SENSORY STIMULATION SYSTEMS

AURAL	PROPRIOCEPTIVE	VISUAL
1. Airflow	1. G-seat	1. LLL TV
2. Engine/propeller	2. G-suit	2. FLIR/SLIR
3. Cockpit pressurization	3. Cockpit motion	3. Visual spectrum
4. Heating/air conditioning	a. Hardware	a. Model board
5. Auxilliary power unit	(1) Pump capacity	(1) Servo tests
6. Weather (rain, hail)	(2) Accumulator capacities	(2) Display tests
7. Landing gear	(3) Pressure limits & regulation	b. CGI
8. Hydraulic system	(4) Operating fluid temperature	(1) Transport delay
9. Electrical System	b. Performance Capability	(2) Display tests
10. Tire Chirp	(1) Excursion limits	c. Area of Interest
11. Wingflap	(2) Velocity limits	
12. Spoiler	(3) Acceleration limits	
	(4) Frequency response	
	(5) Transient response	
	(6) Crosstalk	
	c. Simulation quality	
	(1) Simulated aircraft acceleration tracking	
	(2) Visual/motion Synchronization	

TABLE 5. SIMULATION SYSTEM TESTING AREAS (Continued)

SIMULATED HANDLING QUALITIES	SIMULATION SYSTEMS
1. Flying Qualities	1. Pneumatic (for canopies etc.)
a. Trim Points	2. Hydraulic (control loading, motion etc.)
b. Static longitudinal stability	3. Heating and Air Conditioning (cockpit)
c. Dynamic longitudinal stability	4. Power and Interrupt Monitoring
d. Maneuvering longitudinal stability	5. Plotter
e. Static Lateral-Directional stability	6. Lighting
f. Dynamic Lateral-Directional stability	7. EMI
g. Reduced Power (engine out)	8. Test Equipment and Instrumentation
2. Performance	9. Materials and Workmanship
a. Take off	10. Cockpit
b. Acceleration	a. Location and configuration of all instrumentation, controls and seating
c. Deceleration	
d. Climb	
e. Landing	
f. Stalls/Buffet	
g. Spins	
h. Ground handling	

TABLE 6. SIMULATION FIDELITY PROBLEM AREAS

a. Incorrect Mathematical Model

b. Incorrect Simplifying Assumptions

c. Valid model but incorrect implementation
   - unstable integration
   - incorrect equation sequencing
   - incorrect data entry into model
   - programming mistakes

d. Hardware Problems
   - Hydraulic servos
   - Electrical servos
   - Conversions
   - Computer

e. Physical impossibility of simulation
   (Motion)

TABLE 7. PROJECT 2235 (USAF) TECHNICAL TESTING PROGRAM

	TEST METHOD			
TEST	CGI ASUPT	TMB LAMARS	SAAC/F4-E #18	CGI 2B35
1. System Static Resolution	MTF-OC ANG, RES,-THE TS-A	MTF-OC TS-E	MTF-OC TS-K	Subjective
2. Image Generator Static Resolution	MTF-VSA TS-B	MTF-VSA TS-F	MTF-VSA TS-L	
3. Display Static Resolution		MTF-OC TS-G	MTF-OC TS-M	
4. Image Generator Dynamic Resolution		MTF-VSA TS-F		
5. Brightness, Gray Scale Contrast, Shading (system or display)	PHO TS-C	PHO TS-H(Dis-play) TS-I(System)	PHO TS-N(Display) TS-O(System)	Subjective
6. System Geometric Distortion, AOI Field of View, AOI Dynamic Envelope Size	THE TS-D	THE TS-J	THE TS-P	
7. System Interwindow Continuity	THE TS-D		THE TS-P	Subjective
8. AOI Edge Transition		OC TS-G	OC TS-M	
9. Target Image Location Dynamic Lag			PHO Trigger TS-Q	

TABLE 7. PROJECT 2235 (USAF) TECHNICAL TESTING PROGRAM (Continued)

TEST	CGI ASUPT	TMB LAMARS	SAAC/F4-E #18	CGI 2B35
10. System Rate Accuracy				
11. Camera Gantry Rate Accuracy			X	
12. Color Effects				Subjective

SYMBOLS

1.	ANG.RES.	Angular Resolution
2.	CAM	TV Camera
3.	CCTV	Closed Circuit TV Monitor
4.	CGI	Computer Generated Image
5.	CRT	Cathode Ray Tube
6.	MTF	Modulation Transfer Function
7.	OC	Observer Camera
8.	OSC	Oscilloscope
9.	PHO	Photometer
10.	PROJ	TV Projector
11.	THE	Theodolite
12.	TMB	Terrain Model Board
13.	TS	Test Setup
14.	VSA	Video Signal Analysis
15.	WM	Waveform Monitor

TABLE 8. RECOMMENDED VISUAL DISPLAY TESTING

Television System Tests

- Horizontal and vertical resolution of pickup and display components
- Gray scale
- Video handwidths
- Video signal levels
- Noise levels
- A picture correction
- Gamma Correction
- Linear phase characteristics
- Impedance matching
- Hum
- Target projector blanking

Display Screen Tests

- Screen radius
- Uniformity of curvature
- Seam visibility
- Screen gain

Optical System Tests

- Focal length, back and front focal distances as a function of the zoom position
- Size and position of the entrance pupil for camera lenses and the exit pupil for projection lenses as a function of the zoom position or as a function of field angle for wide angle lenses
- Relative illumination as a function of field angle
- Resolving power as a function of field angle and zoom position and spectral distribution of illumination equal within 10% to that of the normal system operation
- Distortion
- Image size and field of view
- For the target camera lens, depth of field as a function of range and the corresponding zoom position

Model Tests - per specification

Servo, gantry and gimbal system tests

- Motion excursion limits
- Velocity limits
- Acceleration limits
- Positional accuracy
- Threshold sensitivity

TABLE 8. RECOMMENDED VISUAL DISPLAY TESTING (Continued)

<u>Servo, gantry and gimbal system tests</u>

- Repeatability
- Smoothness of operation
- Jitter
- Vibration
- Frequency response
- Deceleration limits

<u>FLOLS tests</u> per the specification

<u>Computer Interface tests</u> per the specification

<u>Controls tests</u> per the specification

<u>System tests</u>

- Horizontal and vertical resolution as a function of field angle consistent with the combined requirements of image luminance, and shades of gray
- Target and background gray scale
- Separate target and background image luminance as a function of field angle
- Separate target and background image distortion
- Target and background image distortion
- Target image size as a function of range
- FLOLS image size and position relative to the target image as a function of range and viewing direction
- Target image and FLOLS image tracking accuracy
- Field of view
- Image jitter
- Target image insetting

<u>System integration tests</u>

<u>Electrical tests</u>

<u>Grounding tests</u>

<u>Electromagnetic interference suppression tests</u>

<u>Structural tests</u>

<u>Human factors tests</u>

TABLE 9. RECOMMENDED AREAS OF FLYING QUALITY AND PERFORMANCE TESTING

- Mechanical characteristics of the control systems
- Steady state trim points
- Longitudinal trim changes
- Static longitudinal stability
- Maneuvering stability
- Dynamic longitudinal stability
- Static lateral-directional stability
- Dynamic lateral-directional stability
- Engine out flying qualities
- Ground handling characteristics
- Takeoff characteristics
- Airflight characteristics
- Landing characteristics
- Engine-out performance
- Engine statics
- Engine dynamics

TABLE 10. RECOMMENDED AREAS OF COCKPIT MOTION TESTING

System Attributes

- Static accuracy
- Repeatability
- Linearity
- Excursion Limits
- Velocity Limits
- Acceleration Limits
- Crosstalk
- Long term drift
- Smoothness
- Stability
- Cue Synchronization

Dynamic Performance

- Frequency response
- Transient response

Simulation Attributes

- Buffet
- Landing, Takeoff
- Propulsion Effects
- Rough Air
- Trim changes
- Stores release
- Tactical maneuvering
- Stall
- Spin

Miscellaneous tests

- Freeze
- Crash
- Reset
- Isolation
- Manual Operation

TABLE 11. RECOMMENDED AREAS OF VISUAL DISPLAY SYSTEM TESTING

System Tests - Static

- Static Accuracy
- Image Size and Perspective

System Tests - Dynamic

- Transient Response
- Steady State Time Lags
- Frequency Response

System Tests - Simulation Attributes

System Tests - Interface Performance

System Tests - Displays

- Luminance
- Resolution
- Contrast
- Depth of Field
- Field of View
- Geometric Distortion and Linearity
- Display Refresh Rate
- Raster Burn
- Multiple Channel Video Tracking
- Multiple Channel Luminance Tracking

Infinity Display Optics Tests

- Viewing Volume
- Collimation
- Mirror Tests

Display Tests - Color Performance

- Convergence
- Color capability
- Color tracking

Display Tests - Zoom optics

- Magnification
- Optical Axis Shift

Model Board Tests

- Texture
- Color
- Illumination
- Dimensions

TABLE 11. RECOMMENDED AREAS OF VISUAL DISPLAY SYSTEM TESTING (Continued)

Servo Tests

- Excursion Limits
- Velocity Limits
- Acceleration Limits
- Static Accuracy
- Repeatability
- Dynamic Accuracy
- Transient Response
- Frequency Response
- Reset Speed

Television System Tests

- Bandwidth
- Gamma
- Signal to Noise
- Resolution

Television Camera Tests

- Geometric Distortion
- Resolution
- Gray Scale
- Luminance

Optical System Tests

- Image size
- Entrance Pupil
- Depth of Field
- Focal Length

TABLE 12. OPTIMUM SEQUENCING OF TESTS

TEST	INPUT	RECORDED DATA	REDUCED DATA
1. Flight cockpit controls (all) control cycles	1. Steps 2. Slow ramps	1. Surface displacments 2. Control displacements 3. And forces	1. Control force per control deflection 2. Surface deflection per control deflection 3. Time lags 4. Breakout forces 5. Hysteresis loops
2. Longitudinal	Computer Control 1. Step 2. Doublet Several sizes 3. Altitude	1. Elevator position 2. Pitch angle 3. Pitch angle rate 4. Angle of attack 5. Angle of attack rate 6. Normal acceleration 7. Flight path angle (all without instrument dynamics) 8. Calibrated Air speed 9. Altitude 10. Cockpit motion a. Pitch acceleration, velocity, altitude b. Heave acceleration, velocity, displacement	1. Short period frequency and damping ratio 2. Phugoid frequency and damping ratio 3. Time to first peak of responses 4. Variation of characteristics with altitude and airspeed 5. Linearity of the model 6. Resolution of the model 7. Operating time and effects of raising gears, flaps, etc. 8. Thrust and drag and all engine statics vs equlibrium Mach number 9. From the steady static of the dynamic responses a. Angle of attack per normal acceleration b. Elevator deflection per pitching rate c. Elevator deflection per angle of attack d. Elevator deflection per normal acceleration e. Trim elevator deflection

TABLE 12. OPTIMUM SEQUENCING OF TESTS (Continued)

TEST	INPUT	RECORDED DATA	REDUCED DATA
Longitudinal		c. Surge acceleration velocity and displacement	10. For each condition tested, make small changes in elevator deflection about trim noting the effects on airspeed, pitch angle, angle of attack and flight path angle. Using stick force per control deflection allows conversion of results to: a. Stick force per pitching rate b. Stick force per angle of attack rate c. Stick force per normal acceleration d. Stick force per velocity change
		11. Simulated acceleration, velocity and displacement for all 6 degrees of freedom	
		12. Vertical commands to the visual display system 13. Vertical drive on display (after visual display computation)	11. Comparison of six degrees of freedom simulated airframe acceleration, velocities and angular displacements to those delivered by the cockpit motion system. Verify synchronization of cueing. 12. Comparison of vertical display drives with analagous instrument and cockpit motion responses.

TABLE 12. OPTIMUM SEQUENCING OF TESTS (Continued)

TEST	INPUT	RECORDED DATA	REDUCED DATA
3. Lateral-Directional	Step rudder held throughout, after rolled between 5° and 10°, apply opposite aileron step until rolled through wing-level until reach steady-state roll rate. Vary amplitude	1. Control inputs 2. Sideship angle 3. Heading angle 4. Rate of heading angle 5. Roll angle 6. Rate of roll angle 7. Side acceleration 8. Velocity 9. Altitude 10. Cockpit motion a. Roll acceleration, velocity, attitude 11. Simulated acceleration velocity and displacement for all 6 degrees of freedom 12. Horizontal and directional drive commands to visual display apparatus	1. Dutch roll - frequency, damping and time to first peak 2. Spiral mode convergence, time to double amplitude 3. Variation of roll rate with configuration, speed and altitude 4. Linearity of response 5. Resolution of model 6. Side slip angle per rudder deflection 7. Side acceleration per rudder deflection 8. Roll rate per aileron deflection 9. Trim valves of rudder and aileron deflection 10. Using pedal force calibrated as a function of rudder deflection a. Aileron control force per aileron deflection b. Rudder pedal force per rudder deflection c. Side slip angle per rudder pedal force d. Side acceleration per rudder pedal force e. Roll angle per sideslip angle 11. Roll angle per sideslip angle 12. Comparison of six degree of freedom simulated airframe acceleration, velocities and angular displacements to those delivered by the cockpit motion system.

TABLE 12. OPTIMUM SEQUENCING OF TESTS (Continued)

TEST	INPUT	RECORDED DATA	REDUCED DATA
			13. Comparison of lateral-directional drive commands with analogous instrument and cockpit motion drive responses
4. Performance	Throttle intermediate full and steps. Engine out.	1. Pertinent engine variables 2. Drag 3. Angle of attack 4. Pitch angle 5. Flight path 6. Airspeed (on Mach) 7. Altitude 8. Elevator deflection 9. Rudder deflection 10. Cockpit motion a. Six degree of freedom acceleration velocity and even angles 11. Visual display drives - six degree of freedom	1. Thrust VS Mach 2. Drag VS Mach 3. Angle of attack tracking pitch angle with rate of climb equal zero 4. Elevator deflection VS Mach 5. Rudder deflection VS Mach 6. Longitudinal Acceleration VS Mach 7. Airspeed VS time 8. Rate of climb VS altitude 9. Rate of climb VS airspeed 10. Minimum airspeed 11. Maximum air speed 12. Engine dynamics - all pertinent engine variables 13. Cockpit motion responses to power changes and engine out performance 14. Visual display responses to power changes and engine out

TABLE 13. COMPARISON OF AND RECOMMENDATION FOR SIMULATION OF FLYING QUALITIES AND PERFORMANCE TOLERANCES

PARAGRAPH OF VARIABLES	1969 MIL-T 82335A USN	1967 MIL-T 9212B USAF	1965 MIL-T 82335	1959 NTDC 318-1	1952 SDC 911-600A	Recommended	Required Data
Control Systems							
Surface deflection vs. control deflection	-	$5\%\Big\vert_{0^\circ}^{10^\circ}, 1/2^\circ\Big\vert_{10^\circ}^{Max}$	-	-	$.5^\circ + 5\%$	5%	-
Control force vs. control deflection	Lower of 5% or 1% of max	Larger 5% or 1% of max	-	10%	2 lb. + 10%	5%	-
Control deflection vs. trim actuation	-	-	-	Check, no tolerances given	Check, no tolerances given	10%	-
Damping	-	-	-	-	Rudder Time to damp to 1/2amp 15%	15%	D
Natural Frequency	-	-	-	-	-	15%	D
Breakout force	-	-	2% (Nz=1)	10%(knee shape proper)	-	5% and knee shape proper	D Knee Shape
Friction force	-	-	-	-	-	10%	D
Free play	-	-	Lower of .2 in or 20% Dir. Lower of .1 in or 20% Long/Lat	.1 in or 20% of aircraft freeplay	.1 in of aircraft freeplay	20%	-
Control deflection vs. appurtenance actuation	-	-	-	-	-	10%	D
Control force due to angle of attack	-	-	$.5^\circ$	-	-	10%	D
Control force due to pitching rate	-	-	-	10%	-	10%	D
Steady-state Trim Points							
Angle of attack vs. trim airspeed	-	-	-	-	-	10%	-
Control deflection vs. trim airspeed	-	-	15% elevator deflect	-	-	10%	D
Trim surface deflection indication vs. trim airspeed	-	-	-	-	-	20%	-

TABLE 13 (CONT'D). COMPARISON OF AND RECOMMENDATION FOR SIMULATION OF FLYING QUALITIES & PERFORMANCE TOLERANCES

PARAGRAPH OF VARIABLES	1969 MIL-T 82335A USN	1967 MIL-T 9212B USAF	1965 MIL-T 82335	1959 NTDC 318-1	1952 SDC 911-600A	Recommended	Required Data
Optimum approach speed vs. gross weight	-	-	-	-	-	5 KIAS	-
Trim surface deflection vs. gross weight	-	-	$.5^0$	-	-	10%	D
<u>Longitudinal Trim Changes Due to Thrust Changes and Activation of Appurtenances</u>							
During appurtenance activation (e.g., landing gear, wing flaps, speed brakes, retractable , etc.)							
Control position vs. time	-	-	-	$.5^0$	$.5^0$+5% fighter, $.5^0$+ 10% patrol	$.5^0$	
Control force vs. time	-	-	-	10%	2 lb.+10% fighter, 5 lb.+10% patrol	10%	
Pitch angle vs. time	-	-	-	-	-	1^0	D
Angle of attack vs. time	-	-	-	-	-	1^0	D
Altitude vs. time	-	-	-	-	-	Lesser of 10 ft. or 10% of the total change in altitude	D
Airspeed vs. time	-	-	-	-	-	Lesser of 5 KIAS or 10% of total change in airspeed	D
Control position vs. appurtenance	-	-	$.5^0$	$.5^0$	$.5^0$+5%fighter, .5% + 10% patrol	$.5^0$	
Control force vs. appurtenance	-	-	10%	10%	2 lb.+10% fighter, 5 lb.+10% patrol	10%	
Pitch angle vs. appurtenance	-	-	-	-	-	1^0	D

TABLE 13 (CONT'D). COMPARISON OF AND RECOMMENDATION FOR SIMULATION OF FLYING QUALITIES & PERFORMANCE TOLERANCES

PARAGRAPH OF VARIABLES	1969 MIL-T 82335A USN	1967 MIL-T 9212B USAF	1965 MIL-T 82335	1959 NTDC 318-1	1952 SDC 911-600A	Recommended	Required Data
Angle of attack vs. appurtenance	-	-	-	-	-	1^{0}	D
Altitude vs. appurtenance	-	-	-	-	-	Lesser of 10 ft. or 10% of total change in altitude	D
Airspeed vs. appurtenance	-	-	-	-	-	Lesser of 5KIAS or 10% of total change in airspeed	D
Static Longitudinal Stability							
Control deflection vs. airspeed	$.5^{0}$	-	$.5^{0}$	-	$.5^{0}$+5% fighter or $.5^{0}$+10% patrol	$.5^{0}$	-
Control force vs. airspeed	2 lb.	-	2 lb.	-	2 lb.+10% fighter or 5 lb.+10%patrol	2 lb.	-
Angle of attack vs. airspeed	-	-	-	$.05^{0}$	-	1^{0}	-
Rate of climb vs. airspeed	-	-	-	-	-	10%	-
(Surface deflection vs. constant pitch attitude)	Lower 10% or 2% of max	5% or 1% of max	-	-	-	-	-
Maneuvering Stability							
Control deflection vs. normal acceleration	See Note (1)	-	See Note (1)	-	$.5^{0}$+5% fighter, $.5^{0}$+10% patrol	10% of deflection from trim valve	-
Control force vs. normal acceleration	See Note (1)	-	See Note (1)	10%	2 lb.+10% fighter 5 lb.+10% patrol	10%	
Angle of attack vs. normal acceleration	-	-	-	-	-	10% of excursion from trim valve	D

TABLE 13 (CONT'D). COMPARISON OF AND RECOMMENDATION FOR SIMULATION OF FLYING QUALITIES AND PERFORMANCE TOLERANCES

PARAGRAPH OF VARIABLES	1969 MIL-T 82335A USN	1967 MIL-T 9212B USAF	1965 MIL-T 82335	1959 NTDC 318-1	1952 SDC 911-600A	Recommended	Required Data
Dynamic Longitudinal Stability							
Short Period	See Note (2)	-	-	-	-	-	-
Frequency vs. airspeed	See Note (2)	5%	See Note (2)	15%	1/4 sec + 30%	10%	-
Damping vs. airspeed	See Note (2)	5%	See Note (2)	15%	(Time to damp 1/10-1/4sec+30%)	10%	-
Time to first peak	-	-	-	10%	-	10%	-
Phugoid							
Frequency vs. airspeed	50% $\lvert \omega_{ap} < 0.1\, \omega_{asp}$ 20% otherwise	5%	50% $\lvert \omega_{ap} < .1\, \omega_{asp}$ 20% otherwise	30%	25%	20%	
Damping vs. airspeed	.05 $\lvert \zeta < .3$, .1 $\lvert \zeta \geq .3$	5%	.05 $\lvert \zeta \leq .3$, .1 $\lvert \zeta > .3$	Larger of .05 or 20%,AC same sign	(subsidence ratio 15%)	Same sign as aircraft and lesser of .05 or 20%	-
PHASING							
Longitudinal control deflection vs. time	-	-	-	-	Check	-	-
Longitudinal control force vs. time	-	-	-	-	-	10%, time to first peak 10%	D
Longitudinal control surface vs. time	-	-	-	-	-	10%, time to first peak 10%	D
Pitch angle vs. time	-	-	Time to first peak 10%, amplitude 10%	-	Check	10%, time to first peak 10%	D
Pitch rate vs. time	-	-	Time to first peak 10%, amplitude 10%	-	-	10%, time to first peak 10%	D
Angle of attack vs. time	-	-	Time to first peak 10%, amplitude 10%	-	-	10% time to first peak 10%	D
Normal acceleration vs. time	-	-	Time to first peak 10%, amplitude 10%	-	Check	10% time to first peak 10%	D

TABLE 13 (CON'T). COMPARISON OF AND RECOMMENDATION FOR SIMULATION OF FLYING QUALITIES AND PERFORMANCE TOLERANCES

PARAGRAPH OF VARIABLES	1969 MIL-T 82335A USN	1967 MIL-T 9212B USAF	1965 MIL-T 82335	1959 NTDC 318-1	1952 SDC 911-600A	Recommended	Required Data
PHASING							
Rate of Climb vs. time	-	-	-	-	-	10%, time to first peak 10%	D
Airspeed vs. time	-	-	-	-	Check	10%, time to first peak 10%	D
Short period frequency vs normal acceleration	-	-	-	-	-	20%	D
Short period damping vs. normal acceleration	-	-	-	-	-	20%	D
Static Lateral-directional Stability							
Directional control deflection vs. sideslip angle	10% or 2% max surface deflection	5% or 1% max deflection	2^0	5% or 1% of max surface	1^0+5% fighter, 1^0+10% patrol	10%	-
Directional control force vs. sideslip angle	-	-	7 lbs.	-	5 lb+25% fighter, 10 lb+25% patrol	15%	-
Lateral control deflection vs. sideslip angle	10% or 2% max surface deflection	5% or 1% max deflection	$.5^0$	5% or 1% of max surface	1^0+5% fighter, 1^0+10% patrol	5%	-
Lateral control force vs. sideslip angle	-	-	2 lbs.	-	2 lb+25% fighter, 5 lb+25% patrol	15%	-
Roll angle vs. sideslip angle	-	-	-	-	-	10%	-
Longitudinal control deflection vs. sideslip angle	-	-	-	(force 10%)	$.5^0$+5% fighter, $.5^0$+10% patrol (2 lb+10% fighter, 2 lb+10% patrol force)	10%	-
Asymmetric							
Heading angle vs. trim inputs	-	-	-	-	-	15%	D
Roll angle vs. trim inputs	-	-	-	2^0	-	15%	D

TABLE 13 (CONT'D). COMPARISON OF AND RECOMMENDATION FOR SIMULATION OF FLYING QUALITIES AND PERFORMANCE TOLERANCES

PARAGRAPH OF VARIABLES	1969 MIL-T 82335A USN	1967 MIL-T 9212B USAF	1965 MIL-T 82335	1959 NTDC 318-1	1952 SDC 911-600A	Recommended	Required Data
Pitch angle vs. trim inputs	-	-	-	-	-	15%	D
Lateral control deflection vs. trim inputs	-	-	1^{0}+5%/1^{0}+10% fighter/patrol	1^{0}+5% fighter/ 1^{0}+10% patrol		15%	D
Directional control deflection vs. trim inputs	-	-	2^{0}+5%/2^{0}+5% fighter/patrol	1^{0}+5% fighter/ 1^{0}+10% patrol	-	15%	D
Heading angle vs. time (for trim changes)	-	-	-	-	-	15%	D
Roll angle vs. time (for trim changes)	-	-	-	-	-	15%	D
Pitch angle vs. time (for trim changes)	-	-	-	-	-	15%	D
Lateral control deflection vs. time(for trim changes)	-	-	-	-	-	15%	D
Directional control deflection vs. time (for trim changes)	-	-	-	-	-	15%	D
Thrust from failed engine vs. time(for trim changes)	-	-	-	-	-	15%	D
Dynamic Lateral-directional Stability							
Dutch roll period vs. airspeed	-	5%, different amplitudes surface deflection 5% of each other	15%	20%	1 sec + 15%	15%	-
Dutch roll damping vs. airspeed	-	5%	25%	greater .05 or 20%	(Time to damp 1/2 amplitude 15%)	15%	-
Roll to sideslip ratio	-	-	$1\|_{\phi/\beta} \geq 4.25\%\|_{\phi/\beta} < 4$	10%	Check; no tolerance given	10%	-

TABLE 13 (CONT'D). COMPARISON OF AND RECOMMENDATION FOR SIMULATION OF FLYING QUALITIES AND PERFORMANCE TOLERANCES

PARAGRAPH OF VARIABLES		1969 MIL-T 82335A USN	1967 MIL-T 9212B USAF	1965 MIL-T 82335	1959 NTDC 318-1	1952 SDC 911-600A	Recommended	Required Data
Control deflection vs. time	SPIRAL TESTING	Surface deflection vs. yaw rate, acceleration. Lower of 10% or 2% surface deflection	Surface deflection vs. yaw angle, rate. 5% or 1% max surface deflection	-	-	-	-	-
Heading angle vs. time				T_s, 20% $T_s \le 20$ sec; 50% $T_s > 20$ sec	$T_d < 1$ min. T_s, +10%, -20%, 30%	(Time to double amplitude 1 sec+ 25%)	25%, convergent or divergent as AC	-
Roll angle vs. time				-	20%	-	25%, convergent or divergent as AC	-
Control deflection vs. time	ROLL TESTING	Surface deflection vs. roll rate, acceleration. Lower of 10% or 2% surface deflection	Surface deflection vs. roll acceleration, rate 5% or 1% max surface deflection	-	-	2 lb+25% fighter, 5 lb+25% patrol (force) 1°+5% fighter, 1°+10% patrol	-	-
Heading angle vs. time				-	-	(1°+10% on side-slip angle)	5%	-
Roll angle vs. time				-	-	2°+10%	5%	-
Roll rate vs. time				5 deg/sec + 10%	5 deg/sec + 10%	5°/sec+10% fighter 5°/sec+10% patrol	5%	-
LATERAL AND DIRECTIONAL								
Control deflection vs. time	PHASING	-	-	Time to initial response 10%	-	Check, no tolerance given	Time to first peak 10%	D
Control force vs. time		-	-	Time to initial response 10%	-	Check, no tolerance given	Time to first peak 10%	D
Surface deflection vs. time		-	-	Time to initial response 10%	-	Check, no tolerance given	Time to first peak 10%	D
Roll rate vs. time		-	-	Time to initial response 10%	-	Check, no tolerance given	Time to first peak 10%	D
Roll angle vs. time		-	-	Time to initial response 10%	-	Check, no tolerance given	Time to first peak 10%	D
Sideslip angle vs. time		-	-	Time to initial response 10%	-	Check, no tolerance given	Time to first peak 10%	D
Heading angle vs. time		-	-	Time to initial response 10%	-	Check, no tolerance given	Time to first peak 10%	D

TABLE 13 (CONT'D). COMPARISON OF AND RECOMMENDATION FOR SIMULATION OF FLYING QUALITIES AND PERFORMANCE TOLERANCES

PARAGRAPH OF VARIABLES	1969 MIL-T 82335A USN	1967 MIL-T 9212B USAF	1965 MIL-T 82335	1959 NTDC 318-1	1952 SDC 911-600A	Recommended	Required Data
Engine-out Flying Qualities							
Lateral control force vs. roll angle	-	-	-	-	2 lb+25% fighter, 5 lb+25% patrol	15%	D
Lateral control deflection vs. roll angle	-	-	-	-	1°+5% fighter, 1°+10% patrol	15%	D
Directional control force vs. roll angle	-	-	-	-	5 lb+25% fighter 10 lb+25% patrol	15%	D
Directional control deflection vs. roll angle	-	-	-	-	1°+5% fighter, 1°+10% patrol	15%	D
Sideslip angle vs. roll angle	-	-	-	-	-	15%	D
Pitch angle vs. roll angle	-	-	-	-	-	15%	D
During Engine Failure							
Power lever angle vs. time	-	-	-	-	-	15%	D
Roll angle vs. time	-	-	-	-	-	15%	D
Pitch angle vs. time	-	-	-	-	-	15%	D
Yaw angle vs. time	-	-	-	-	-	15%	D
Longitudinal control deflection vs. time	-	-	-	-	-	15%	D
Lateral control deflection vs. time	-	-	-	-	-	15%	D
Direction control deflection vs. time	-	-	-	-	-	15%	D
Airspeed (Mach)	-	-	-	-	-	15%	D
Minimum control ground speed	-	-	10%	-	-	10%	-
Minimum control air speed (static)	-	-	10%	-	-	10%	-
Minimum control air speed (dynamic)	-	-	10%	-	-	10%	-

TABLE 13 (CONT'D). COMPARISON OF AND RECOMMENDATION FOR SIMULATION OF FLYING QUALITIES AND PERFORMANCE TOLERANCES

PARAGRAPH OF VARIABLES	1969 MIL-T 82335A USN	1967 MIL-T 9212B USAF	1965 MIL-T 82335	1959 NTDC 318-1	1952 SDC 911-600A	Recommended	Required Data
Ground Handling Characteristics							
Heading angle vs. time (Parameterized against % nose gear steering)	10%	-	10%	-	-	15%	D
Heading angle vs. time (Parameterized against % differential wheel brake application)	10%	-	10%	-	-	15%	D
Ground speed vs. time (Parameterized against wheel brake application)	-	(stopping time 10%)	-	-	-	15%	D
Lateral control effectiveness speed	-	-	-	-	-	20%	D
Directional control effectiveness speed	5Kt	-	5Kt	Check- but no tolerance	Check- but no tolerance	20%	D
Takeoff Characteristics							
Nosewheel liftoff speed vs. gross weight	2%	2Kt	5%(TO)	5%	5%	5%	-
Nosewheel liftoff time vs. gross weight	(TO + 0, -2 sec.)	(TO + 0, -2 sec.)	5%	(TO distance 20%)	(TO distance 20%)	5%	-
during take-off							
Airspeed vs. time	-	-	-	-	-	5%	-
Rate of climb vs. time	-	-	-	-	-	15%	D
Longitudinal control deflection vs. time	-	-	-	-	(Control force 5 lb. + 10%)	5%	D
Lateral control deflection vs. time	-	-	-	-	-	Qualitative and same sense as AC	D
Directional control deflection vs. tiem	-	-	-	-	-	Qualitative and same sense as AC	D
Pitch angle vs. time	-	$.3^0$	-	-	-	2^0	D
Angle of attack vs time	2^0	$.3^0$	2^0	-	-	2^0	D

TABLE 13 (CONT'D). COMPARISON OF AND RECOMMENDATION FOR SIMULATION OF FLYING QUALITIES AND PERFORMANCE TOLERANCES

PARAGRAPH OF VARIABLES	1969 MIL-T 82335A USN	1967 MIL-T 9212B USAF	1965 MIL-T 82335	1959 NTDC 318-1	1952 SDC 911-600A	Recommended	Required Data
Inflight Characteristics							
Airspeed vs. time (acceleration)	5% (General tolerance)	5% (general tolerance)	Thrust 3% 5% on time	-	5% up to .8 v mat	5%	-
Airspeed vs. time (deceleration)	5% (General tolerance)	5% (General tolerance)	Drag 3% 5% on time	5% $v < 80\%\ v_{mat}$	5% to .8 terminal speed	5%	-
Altitude vs. time	-	-	-	-	Check, but no tolerance	Larger of 5% or 50 ft.	-
Rate of climb vs. airspeed	Larger of 5% or 50 ft/min	5% or 50 ft/min	15%	15% $\lvert R/C \rvert > 50$ fpm BRCS 5%	200 fpm + 10%	Larger of 5% or 50 fpm	-
Speed for best rate of climb	-	-	5%	-	5%	-	-
Maximum speed/configuration (ØR/C)	1%	1%	-	-	5%	1%	-
High speed warning	-	-	-	5% V_{mat}	5% V_{mat}	5% V_{mat}	-
Descent (best time, max range descent)	-	-	-	-	5%	-	-
Buffet onset speed vs. gross weight	1% or 5 Kt	1% or 1 Kt	-	-	-	2%	-
Stall speed vs. gross weight	1% or 5 Kt	1% or 1 Kt	+ 7 - 0 KIAS	5%	5%	2%	-
Limit buffet speed vs. gross weight	-	-	-	-	-	5%	-
Optimum approach speed vs. gross weight	-	-	-	5%	5%	2%	-
Load factor vs. airspeed (Mach)	-	-	-	-	-	.2 g	-

TABLE 13 (CONT'D). COMPARISON OF AND RECOMMENDATION FOR SIMULATION OF FLYING QUALITIES AND PERFORMANCE TOLERANCES

PARAGRAPH OF VARIABLES	1969 MIL-T 82335A USN	1967 MIL-T 9212B USAF	1965 MIL-T 82335	1959 NTDC 318-1	1952 SDC 911-600A	Recommended	Required Data
Angle of attack vs. time	-	-			Checked, no tolerance given		-
Airspeed vs. time	-	-			-		-
Heading angle vs. time	-	-			-		-
Heading angle rate vs. time	during stalls and spins -	-	sequence in order	qualitative	-	Qualitative - all variables in proper sequence and delay characteristics	-
Sideslip angle vs. time	-	-			-		-
Pitch angle vs. time	-	-			-		-
Pitch rate vs. time	-	-			-		-
Roll angle vs. time	-	-			-		-
Roll rate vs. time	-	-			-		-
Altitude vs. time	-	-			-		-
Landing characteristics							
Ground effects holdoff speed	-	-	-	elevator effectiveness	-	5 KIAS	-
Longitudinal control deflection vs. angle of attack	-	-	-	-	-	2^0	-
Longitudinal control force	-	-	-	-	5 lb+10%	-	-
Angle of attack vs. time	-	-		-	-		-
Altitude vs. time	-	-		-	-		-
Rate of climb vs. time	-	-	sequence in order	-	-	Qualitative and all variables of proper delay and sequence	-
Airspeed/groundspeed vs. time	during landings -	-		-	-		-
Longitudinal control deflection vs. time	-	-		-	Check, but no tolerance		-
Spoiler deflection vs. time	-	-		-	-		-

TABLE 13 (CONT'D). COMPARISON OF AND RECOMMENDATION FOR SIMULATION OF FLYING QUALITIES AND PERFORMANCE TOLERANCES

PARAGRAPH OF VARIABLES	1969 MIL-T 82335A USN	1967 MIL-T 9212B USAF	1965 MIL-T 82335	1959 NTDC 318-1	1952 SDC 911-600A	Recommended	Required Data
Drag chute, tail hook, spoiler effectiveness	-	-	qualitative	-	-	qualitative	-
Engine-out performance							
Airspeed (Mach) vs. time (acceleration)	-	-	-	-	5%	10%	-
Altitude vs. time	-	-	-	5%	5%	10%	-
Rate of climb vs. airspeed	-	-	100 ft/min.+10%	100 ft/min.+10%	100 ft/min.+10%	10%	-
Airspeed	-	-	3%	5%	5%	10%	-
Thrust	-	-	3%	-	Checked, but no tolerance	-	-
Service ceiling	-	-	5%	-	-	-	-
Engine Statics							
Controls - power lever position, mixture, propeller controls	5%	2% Max-75%, 5% 75%-0, 5% max.	3^0	3^0	3^0	3^0	-
Fuel flow	5%	5% or .5% of max.	5%	-	-	5%	-
Fuel pressure	10%	10% or .1% of max.	-	-	-	10%	-
Fuel temperature	-	5%	-	-	-	10%	-
RPM	2%	.5%	-	-	-	On ground, idle and MIL-RPM shall equal desired RPM x (1±.01) (elsewhere, RPM shall equal desired RPM x (1±.02))	-
Windmilling RPM	5%	5%	5%	-	Checked, but no tolerance given	RPM shall equal desired RPM x (1±.05)	-

TABLE 13 (CONT'D). COMPARISON OF AND RECOMMENDATION FOR SIMULATION OF FLYING QUALITIES AND PERFORMANCE TOLERANCES

PARAGRAPH OF VARIABLES	1969 MIL-T 82335A USN	1967 MIL-T 9212B USAF	1965 MIL-T 82335	1959 NTDC 318-1	1952 SDC 911-600A	Recommended	Required Data
Idle governing speed	-	2%	15%	15%	15%	RPM shall equal desired RPMx(1±.05)	-
Exhaust gas temperature	3% $\vert^{75\%}_{idle}$, 1.5% $\vert^{max}_{75\%}$	3% $\vert^{75\%}_{idle}$, 1.5% $\vert^{max}_{75\%}$	20^oC	$\pm30^o$ light off, idle, & from 50% NRP to MAT	$\pm30^o$ light off, idle, & from 50% NRP to MRP	3% $\vert^{75\%}_{idle}$, 1.5% $\vert^{max}_{75\%}$	-
Oil pressure	10%	5%	-	-	-	10%	-
Oil temperature	10%	10% or 5% of max	-	-	-	10%	-
Turbine inlet temperature	5^oC	5^o	-	-	-	5^oC	-
Pressure ratio	2% below cruise, 1% above	2% below cruise, 1% above	-	-	-	2% below cruise, 1% elsewhere	-
Thrust	3% or .3% max.	2% or .2% of max.	3%	5%	-	2%	-
Torque pressure	300 in-lb	300 in-lb	-	-	-	300 in-lb	-
Temperature (cylinder head)	20^oC	-	-	-	-	20^oC	-
Shaft horsepower	-	20 bhp,50 elsewhere	-	-	-	2%	-
Engine vibration	-	20%	-	-	-	Qualitative	-
Manifold pressure	-	-	-	-	-	5%	-
Nozzle area	-	-	-	-	-	10%	-
Fuel consumpiton (warmup, taxi, runup, takeoff)	-	-	15%	15%	15%	15%	-
Specific fuel consumption	-	-	5%	5%	5%	5%	-
Specific range	-	-	10%	10%	10%	10%	-
<u>Engine Dynamics</u>							
Fuel flow rate of change	25%	25%	-	-	-	25%	-
Fuel depletion rate	5%	5% or .3% of max	-	-	-	5%	-
Fuel pressure rate of change	25%	25%	-	-	-	25%	-
Fuel temperature rate of change	-	25%	-	-	-	25%	-

TABLE 13 (CONT'D). COMPARISON OF AND RECOMMENDATION FOR SIMULATION OF FLYING QUALITIES AND PERFORMANCE TOLERANCES

PARAGRAPH OF VARIABLES	1969 MIL-T 82335A USN	1967 MIL-T 9212B USAF	1965 MIL-T 82335	1959 NTDC 318-1	1952 SDC 911-600A	Recommended	Required Data
Engine acceleration/ deceleration	15%/15%	10%/ -	15%/15%	15%/15% | Idle < 80%	15% | 80% idle	10%	-
Exhaust gas temperature rate of change	25%	25%	-	-	-	25%	-
Oil pressure rate of change	25%	25%	-	-	-	25%	-
Oil temperature rate of change	25%	25%	-	-	-	25%	-
Turbine inlet temperature rate of change	25%	25%	-	-	-	25%	-
Pressure ratio rate of change	25%	25%	-	-	-	25%	-
Thrust rate of change	-	-	-	-	-	5%	-
Torque pressure rate of change	25%	25%	-	-	-	5%	-
Light off time	10%	-	10%	25%	25%	10%	-

NOTES

Note (1)

Conditions	F_{BO}	F_{S/N_z}	Tolerance
(a) Fighter aircraft Attack aircraft	$<.25\ [(F_s/N_z)_o \times 1.0g]$	> 7 lb/g	3 lb/g
	$<.25\ [(F_s/N_z)_o \times 1.0g]$	4 lb/g $\leq F_s/g \leq 7$ lb/g	4 lb/g $\leq F_s/g \leq 7$ lb/g
	$<.25\ [(F_s/N_z)_o \times 1.0g]$	< 4 lb/g	15%
	$>.25\ [(F_s/N_z)_o \times 1.0g]$	all	$(-0.5(F_s/N_z) + 15)$%
(b) Patrol and logistics aircraft	$<.05\ [(F_s/N_z)_o \times 1.0g]$	> 55 lb/g	10 lb/g
	$<.05\ [(F_s/N_z)_o \times 1.0g]$	40 lb/g $\leq F_s/N_z \leq 55$ lb/g	40 lb/g $\leq F_s/N_z \leq 55$ lb/g
	$<.05\ [(F_s/N_z)_o \times 1.0g]$	< 40 lb/g	20%
	$>.05\ [(F_s/N_z)_o \times 1.0g]$	all	$(-0.145(F_s/N_z) + 20$%

Note (2)

Variable	Condition	Tolerance
Short period damping Fighter, attack	damping ratio	
	$\geq .55$	.1
	$.1 < x \leq .55$	.05
	$0 < x \leq .1$	.025 but same sign as aircraft
damping Patrol, logistics	$> .4$	.1
	$\leq .4$	.05 same sign as aircraft
	undamped natural frequency (Hz)	
frequency Fighter, attack	$\geq .7$	.1 Hz
	$< .7$	.5 not imaginary unless aircraft is
frequency Patrol, logistics	$> .4$	.1 Hz
	$\leq .4$	.05 Hz not imaginary unless aircraft is

Note (3)

Condition	F_{BO}	F_s/N_z	Tolerance
(a) Fighter and attack	$< .25\ F_s$	> 4 lb/g	10%
	$< .25\ F_s$	< 4 lb/g	15%
	$\geq .25\ F_s$	all	$-.5\ (F_s/N_z)_o + 15$%
(b) Patrol and Logistics	$< .05\ F_s$	> 55 lb/g	10 lb/g
	$< .05\ F_s$	$40 \leq F_s/N_g < 55$ lb/g	40 F_s/N_z 55 lb/g
	$< .05\ F_s$	< 40 lb/g	20%
	$\geq .05\ F_s$	all	$(-.145\ F_s + 20$%)

TABLE 14. COMPARISON OF AND RECOMMENDATION OF SIMULATION OF COCKPIT MOTION TOLERANCES

SYSTEM TEST	MIL-82335	MIL-9212	MIL-STD-1558	TOLERANCES RECOMMENDED
1. Positional accuracy	NTG*	NTG	1%	1 percent of full scale deflection
2. Repeatability	NTG	NTG	NTG	0.5 percent of initial response
3. Linearity	NTG	NTG	NTG	Response to unit commands near full deflection shall be within 2% of the response mid-deflection
4. Excursion limits	NTG	T, NTG	NTG	1 percent
5. Velocity limits	NTG	NTG	NTG	5 percent
6. Acceleration limits	NTG	NTG	Greater than spec.	5 percent
7. Crosstalk	NTG	NTG	2% offending servo	Less than 2% of the offending servo amplitude
8. Long term drift	NTG	NTG	1% in 12 hr.	Less than 1% of full scale deflection for each degree of freedom
9. Smoothness	not erratic no hunting	not erratic no hunting	.04g @.5 Hz	Spurious accelerations shall be less than 0.04g for linear degrees of freedom and $1°/sec^2$ for angular degrees of freedom
10. Stability	NTG	NTG	.015g	Instability or spurious accelerations shall be lower than 0.015g for linear degrees of freedom and $1/2°/sec^2$ for angular degrees of freedom

* NTG - No Tolerance Given

TABLE 14. COMPARISON OF AND RECOMMENDATION OF SIMULATION OF COCKPIT MOTION TOLERANCES (Continued)

SYSTEM TEST	MIL-82335	MIL-9212	MIL-STP-1558	TOLERANCES RECOMMENDED
11. Synchronization of cueing system responses	NTG	Synchronized with indicators	no noticeable lag	Cueing system response shall occur within 50 msec of each other except for normally delayed responses
Dynamic Performance a. Frequency response - Bode Plots	NTG	Freq .01 1 Gain 10%* 5%* *10% angular 5% translational Phase 10°	Freq Gain .1-5 ±2dB .5-1. ±4dB 1.-1.7 ±8dB 1.7-5 NA Phase 15° 40° 90° Perc.	The amplitude and phase responses shall be within the following tolerances of the values specified in the detail specification TOLERANCE Frequency / Gain / Max Phase Shift 0.1 0.5 ±2dB 15° 0.5 1.0 ±2dB 45° 1.0 2.0 ±3dB 90° 2.0 3.0 ±3dB 120° 3.0 5.0 ±5dB -8dB 130°
Phasing	NTG	T, NTG	No noticeable errors	Analogous system responses shall occur within 5° of each other
b. Transient Response 1. Step	NTG	NTG	Response in less than .05 Sec	The lowest natural frequency shall be greater than 5 Hz. Damping shall be 0.6 to

TABLE 14. COMPARISON OF AND RECOMMENDATION OF SIMULATION OF COCKPIT MOTION TOLERANCES (Continued)

SYSTEM TEST	MIL-82335	MIL-T-9212	MIL-D-1558	TOLERANCES RECOMMENDED
				critical. Time to 0.632 of response amplitude shall be as specified in the detail specification $\pm 10\%$
2. Sinusoid	NTG	NTG	-	Verify smoothness, spurious accelerations shall be less than 0.08g for linear degrees of freedom and $2°/sec^2$ angular degrees of freedom

TEST SIMULATION ATTRIBUTES	MIL-T-82335	MIL-T-9212	MIL-STD-1558	COMMENT OR TOLERANCE
Evaluate the effects of the following: 1. Buffet onset and associated effects of airspeed, normal acceleration, angle of attack, or other appropriate parameters for CR and PA configurations 2. Landing, takeoff and runway maneuvers PA, TO configurations 3. Propulsion	1. Shall be representative of aircraft	1. Washout slowly return to normal 2. Properly respond sponds	1. Washouts shall be imperceptible 2. Movements shall correspond to aircraft motions	1. Washout accelerations shall be less than 0.04g for linear axes and $2°/sec^2$ for angular degrees of freedom 2. Motion responses shall begin within 50 msec of simulated airframe responses 3. Motion responses shall be properly oriented with respect to the simulated airframe responses

TABLE 14. COMPARISON OF AND RECOMMENDATION OF SIMULATION OF COCKPIT MOTION TOLERANCES (Continued)

TEST SIMULATION ATTRIBUTES	MIL-T-82335	MIL-T-9212	MIL-STD-1558	COMMENT OR TOLERANCE
system. PA, CR configurations				
4. Rough or turbulent air				
5. Actuation of appurtenances such as landing gear, wing flaps, wheel brakes, speed brakes, drague chute, and other aerodynamic lift or drag devices				
6. Release of stores				
7. Tactical maneuvering effects such as air-to-ground weapon delivery				
8. Stall				
9. Spin				
10. Pulse and 10 cycles of sinusoidal control deflections separately for the longitudinal, lateral, and direction axes.				

TABLE 14. COMPARISON OF AND RECOMMENDATION OF SIMULATION OF COCKPIT MOTION TOLERANCES (Continued)

MISCELLANEOUS TESTS	MIL-T-82335	MIL-T-9212	MIL-STD-1558	COMMENT OR TOLERANCE
1. Freeze	NTG	NTG	NTG	The motion system shall remain in the position it was in when the freeze was initiated
2. Crash	NTG	NTG	NTG	The motion system shall return to the level and lock position with rates less than 4°/sec(angular) or 4 inc/sec (linear) and 0.1g
3. Reset	NTG	NTG	NTG	The motion system shall return to the initial condition position with rates less than 4°/sec (angular) or 4 in/sec (linear) and 0.1g
4. Isolation	NTG	NTG	NTG	The flight simulator operation shall not be interrupted in any fashion. Upon deactivation of the motion system, the platform shall return to its level rests at rates less than 4°/sec (angular) or 4 in/sec (linear) at less than 0.1g (linear) or $4°/sec^2$ (angular)
5. Manual	NTG	NTG	NTG	

TABLE 15. COMPARISON OF AND RECOMMENDATION FOR VISUAL DISPLAY SIMULATION TOLERANCES

TESTS	MIL-T-9212 TOLERANCE	RECOMMENDED TOLERANCE
Static		
1. Static accuracy		
a. Roll excursion	10% of computed value	0.5°
b. Pitch excursion	10% of computed value	0.5°
c. Yaw excursion	10% of computed value	0.5°
d. X excursion	25 ft of computed value	0.5% of command
e. Y excursion	25 ft of computed value	0.5% of command
f. Z excursion	10 ft below 100 ft, 10% of computed above 100 ft	0.5% of command
2. Image size and perspective	Shall be correct, no tolerance given	5% of theoretical
Dynamic Performance		
1. Transient response	No tolerance given	No overshoot allowed greater than 2%, i.e., damping greater than or equal to .8. The 10% settling time shall be as specified ± 20 msec. (If no 10% settling time is recommended, a 100 msec maximum is suggested.)
2. Steady state time lags	No tolerance given	As specified ± 10%. If not specified, recommend lag to be less than 60 msec.
3. Frequency	No tolerance given	As specified ± 10% of amplitude (not measured in Db) and phase
Simulation Attributes		
1. Scene content	No tolerance given	At least the specified number of edges or surfaces
2. Scene movement	No tolerance given	No erratic movement or jitter shall occur in flight.

TABLE 15. COMPARISON OF AND RECOMMENDATION FOR VISUAL DISPLAY SIMULATION TOLERANCES (Continued)

TESTS	MIL-T-9212 TOLERANCE	RECOMMENDED TOLERANCE
3. Fresnel Lens Optical Landing System (as applicable)	No tolerance given	1/10 ball, subjective appraisal of FLOLS size as a function of range.
4. Visual Approach Slope Indicator - VASI - (as applicable)	No tolerance given	0.1%
5. Strobe light operation	No tolerance given	DNA
6. Atmospheric Effects - clouds, haze, fog, etc.	No tolerance given	DNA
7. Directional lights (as applicable)	No tolerance given	DNA
8. Runway markings (as applicable)	No tolerance given	DNA
9. Approach lights (as applicable)	No tolerance given	DNA
10. Horizon intensity (as applicable)	No tolerance given	DNA
11. Beacon light	No tolerance given	DNA
12. Carrier edge lights (as applicable)	No tolerance given	As specified, DNA
13. Carrier runway center lights (as applicable)	No tolerance given	As specified, DNA
14. Carrier runway edge lights (as applicable)	No tolerance given	As specified, DNA
15. Carrier runway athwartships lights (as applicable)	No tolerance given	As specified, DNA
16. Carrier axial deck bow, athwartship lights (as applicable)	No tolerance given	As specified, DNA
17. Carrier vertical dropline lights (as applicable)	No tolerance given	As specified, DNA
18. Eyeheight above runway	No tolerance given	DNA
19. Mission playback (as applicable)	No tolerance given	Subjective - DNA
20. Demonstration maneuvers (as applicable)	No tolerance given	DNA

TABLE 15. COMPARISON OF AND RECOMMENDATION FOR VISUAL DISPLAY SIMULATION TOLERANCES (Continued)

TESTS	MIL-T-9212 TOLERANCE	RECOMMENDED TOLERANCE
a. Basic powered flight maneuvers		
b. Ground taxi		
c. Takeoff (normal, field)		
d. Takeoff (catapult)		
e. Approach		
f. Waveoff		
g. Landing (Normal)		
h. Landing (arrested)		
i. Inflight refueling		
j. Weapons delivery		
k. Air combat maneuvering		
Interface Performance		
1. Freeze	No tolerance given	Subjective - DNA
2. Crash	No tolerance given	Subjective - DNA
3. Reset	No tolerance given	Subjective - DNA
4. Isolation	No tolerance given	Subjective - DNA
5. Systems synchronization (visual, motion and instrument simulation)	No tolerance given	Response initiation shall occur within 20 msec of each other.
Displays		
1. Luminance, and uniformity of luminance for background and targets	Greater than minimum specified, shall not vary more than 30% throughout the display	Greater than minimum specified value with corner luminance no less than 70% of center luminance.
2. Resolution (on and off axis) horizontal and vertical.	Greater than specified minimum	On axis, specification minimum; off axis, no less than 80% of the on axis minimum.
3. Contrast or contrast ratio	Greater than minimum	Greater than minimum specification value.
4. Depth of field (not applicable to CGI Systems)	50 to 30,000 ft No tolerance given	Greater than the specification minimum.
5. Field of view	In detail specification	1°

TABLE 15. COMPARISON OF AND RECOMMENDATION FOR VISUAL DISPLAY SIMULATION TOLERANCES (Continued)

TESTS	MIL-T-9212 TOLERANCE	RECOMMENDED TOLERANCE
6. Geometric distortion and linearity	"Shall be correct," No tolerance given	Grids within 5° of optical axis, 6 arc min deviation; from 5° to 100°, 1% of raster height; greater than 100°, 1°.
7. Display refresh rate	No tolerance given	Greater than specification minimum
8. Raster burn	No tolerance given	Not discernible
9. Multiple channel video tracking (as applicable)	No tolerance given	Slope changes shall not exceed the greater of 1° or 0.5°
10. Multiple channel luminance tracking	No tolerance given	15%
Infinity Display Optics		
1. Viewing volume	No tolerance given	Equal or better than specified
2. Collimation	6 arc minutes on axis 40 arc minutes off axis	$\pm$ .02 diopters of specified value
3. Mirror tests (as applicable)		
a. Radius (spherical mirror)	No tolerance given	The maximum blur circle dimension composing the image of the stop, on the opposite side of the center of curvature shall be within 10% of the specified value
b. Uniformity of curvature (spherical mirror)	No tolerance given	The radius variation shall be less than 0.5%
c. Mirror smoothness (spherical)	No tolerance given	Subjective - An observer located at the approximate center of curvature shall not observe the reflex image of the edge to have any waviness (caused by surface face ripples) or feathery raggedness (orange

TABLE 15. COMPARISON OF AND RECOMMENDATION FOR VISUAL DISPLAY SIMULATION TOLERANCES (Continued)

TESTS	MIL-T-9212 TOLERANCE	RECOMMENDED TOLERANCE
		peel effect) or any other irregularity using only the unaided eye.
Color Performance		
1. Convergence	No tolerance given	In a circular area of diameter .8 times picture height convergence error shall be less than 0.1% of picture height. In a circular area whose diameter is equal to the height, the convergence error shall be less than 0.2%. In the remaining corner area, the error shall be less than 0.5%.
2. Color capability	No tolerance given	Better than specification value
3. Color tracking (as applicable)	No tolerance given	DNA
Zoom Optics		
1. Magnification	No tolerance given	5%
2. Optical Axis Shift	No tolerance given	Target shift shall not exceed 5 arc minutes
General Parameters		
1. Texture	No tolerance given	DNA
2. Color	No tolerance given	DNA
3. Illumination	No tolerance given	Better than specified minimum
4. Dimensions (overall)	No tolerance given	0.5 feet
Servo Tests		
1. Excursion limits	No tolerance given	Equal to or greater than specified
2. Velocity limits	No tolerance given	Equal to or greater than specified

TABLE 15. COMPARISON OF AND RECOMMENDATION FOR VISUAL DISPLAY SIMULATION TOLERANCES (Continued)

TESTS	MIL-T-9212 TOLERANCE	RECOMMENDED TOLERANCE
3. Acceleration limits	No tolerance given	Equal to or greater than specified
4. Static accuracy (positional)	No tolerance given	.15% of command
5. Repeatability	No tolerance given	.02% of initial command
6. Dynamic accuracy (velocity tracking)	No tolerance given	Response amplitude shall be within 10% of command. Velocity fluctuations shall be less than 2% of command
7. Transient response	No tolerance given	Damping, .1 of specified value; natural frequency, .2 Hz of specified. If not specified, recommend $.7 \pm .1$ damping, 25 ± 3 radians per second frequency
8. Frequency response	No tolerance given	0 to 1 Hz, 2db, 10° 1 Hz to 2 Hz, 4db, 20°, 2 Hz to 5 Hz, 8db, 40°
9. Reset speed	No tolerance given	10% of specified. If not specified, 10 inches/sec
Television System		
1. Bandwidth	No tolerance given	Specification value ± 5 MHz. If not specified, recommend 1.5 picture elements (black and white) per sec at 3db down
2. Gamma	No tolerance given	Within 10% of specified or unity if not specified
3. Signal to noise	35db down	Specification value ± 2db. If not specified, recommend 40 db down.

TABLE 15. COMPARISON OF AND RECOMMENDATION FOR VISUAL DISPLAY SIMULATION TOLERANCES (Continued)

TESTS	MIL-T-9212 TOLERANCE	RECOMMENDED TOLERANCE
4. Resolution	Better than: Pilot's eye pos'n 8 min of arc 6 min of arc 4 min of arc Modulation Transfer 50% 25% 10%	Greater than specified, recommend 700 TV lines minimum in center, 550 in corners
Television Camera		
1. Geometric Distortion	Given as system tolerance	2% of picture height
2. Resolution	Given as system tolerance	Per Table I of EIA Standard RS-343-A, Electrical Performance Standards for High Resolution Monochrome Closed Circuit Television Camera
3. Gray Scale	Given as system tolerance	All ten steps of the EIA resolution chart shall be visible
4. Luminance		Detail specification values ±5%
Optical System		
1. Image size	No tolerance given	All tolerances required for this section are to be supplied in the Detail Specification
2. Entrance Pupil size and position	No tolerance given	
3. Depth of field	No tolerance given	
4. Focal length	No tolerance given	

REFERENCES

SECTION I

1. Mackie, Robert R.; Kelley, Gene R.; Moe, Gary L. and Meckerikoff, Michael: "Factors Leading to the Acceptance or Rejection of Training Devices," NAVTRAEQUIPCEN 70-C-0276-0, August 1972.

2. Ryan, L. E.; Puig, J. A.; Micheli, G. S.; and Clarke, J. C.: "An Evaluation of the Training Effectiveness of Device 2F90, TA-4J Operational Flight Trainer: Part 1: The B-Stage," NAVTRAEQUIPCEN Technical Report IH-207.

3. O'Conner, F. E. CAPT USN: Shinn, B. J. Dr. and Bunker, W. M., Dr.: "Prospects, Problems and Performance - a case study of the First Pilot Trainer Using CGI Visuals," Proceedings of the Sixth Naval Training Equipment Center and Industry Conference, NAVTRAEQUIPCEN IH-226, November 13, 1973.

4. Harris, W. T.: "Device 2F90 Flying Qualities and Performance Evaluation and Discrepancy Correction," NAVTRAEQUIPCEN Technical Report IH-245, September 1975.

SECTION II

5. Anon: MIL-T-23991, Military Specification - "Training Devices Military; General Specification for"

6. Anon: MIL-T-82335, Military Specification - "Trainer, Fixed-Wing, Flight; General Specification For"

7. Anon: MIL-T-9212, Military Specification - "Trainer, Flight Simulator, Aircraft, General Requirements For"

8. Anon: SDC-911-600, Department of the Navy Office of Naval Research - Special Devices Center, General Specification for Testing of Operational Flight Trainers and/or Tactics Trainers Simulation, 15 August 1952.

9. Newell, Fredrick D.: NAVTRADEVCEN 318-1, "Final Report Dynamic Test Program for Weapon System Trainers," April 1959 (AD-228942), Unclassified.

10. Newell, Fredrick D; Schelhorn, Arno E.: NAVTRADEVCEN 318-2 "Final Report Phase III; Dynamic Test Program for Weapon System Trainers," March 1961 (AD-323180), Confidential.

11. Schelhorn, Arno E.: NAVTRADEVCEN 318-3 "Preliminary Design Report for NTDC Research Model Test Equipment," February 1960, Unclassified.

12. Newell, Fredrick D.; Schelhorn, Arno E.: NAVTRADEVCEN 318-4, "Summary Report Phase IV: Dynamic Test Program for Weapon Systems Trainers," June 1961 (AD-262667), Unclassified.

13. Newell, Fredrick D.; Schelhorn, Arno E.: NAVTRADEVCEN 318-5, "Final Report Addendum: Application of Dynamic Test Techniques to Weapon System Trainers," September 1969 (AD-484396), Unclassified.

14. Anon: U.S. Naval Training Device Center 31-610, "General Specification for Functional Test Requirements - Fixed Wing Aircraft-Weapon System Trainers (Flight)," 30 August 1963.

15. Anon: MIL-STD-470 Military Standard: Maintainability Program Requirements (For Systems and Equipments).

16. Anon: MIL-STD-471 Military Standard; Maintainability Demonstrations.

17. Anon: MIL-STD-781 Military Standards; Reliability Tests, Exponential Distribution.

18. Anon: MIL-STD-785, Military Standard; Requirements for Reliability Program (For Systems and Equipments).

19. Anon: MIL-STD-826, Military Standard; Electromagnetic Interference Test Requirements and Test Methods.

20. Anon: MIL-STD-876 (USAF), Military Standard; Digital Computation Systems for Real-time Training Simulators.

21. Langdon, S. D. LCDR USN, "Fixed Wing Stability and Control Theory and Flight Test Techniques," Naval Test Pilot School Flight Test Manual, USNTPS-FTM-No 103, August 1969.

22. Small, S. M., LCDR USN and Prueher, J. W.: "Fixed Wing Performance Theory and Flight Test Techniques," Naval Test Pilot School Flight Test Manual USNTPS-FTM No 104, July 1972.

23. Anon: "Stability and Control," FTC-TIH-64-2004, USAF Aerospace Research Pilot's School, Rev. November 1964.

24. Jacobs, W. B.: "Automated Simulator Test and Checkout," Goodyear Engineering Report GER16011, January 1974, (Ref. IR & D Project No. 0509-73-D5) Proprietary.

SECTION III

SECTION IV

SECTION V

25. Hutton, D. P.; Burke, D. K.; Englehart, J. D.; Wilson Jr., J. M.; Romaglia, F. J.; Schneider, A. J.: "Final Report Project 2235, Air-to-Ground Visual Simulation Demonstration," P. E. 64227F, October 1976.

26. Harshbarger, John H.; Gill, Arthur T.: "Development of Techniques for Evaluation of Visual Simulation Equipment," AMRL-TDR-64-49, August 1964.

27. Harshbarger, John H.: "Test and Evaluation of Electronic Image Generation and Projection Devices - Volume I - Evaluation Technique," AMRL-TR-65-116, Vol. I, August 1965.

28. Harshbarger, John H.; Basinger, James D.: "Test and Evaluation of Electronic Image Generation and Projection Devices - Volume II - Evaluation of Television Systems," AMRL-TR-65-116, Volume II, November 1965.

29. Harshbarger, John H.; Basinger, James D.: "Test and Evaluation of Electronic Image Generation and Projection Devices - Volume III - Evaluation of Projection Screens," AMRI-TR-65-116, Volume III, December 1965.

30. Driskell, Carl R.: "Capabilities in Wide Angle Visual Technology," NAVTRAEQUIPCEN IH-237, December 1974.

31. Lindenberg, Klaus: "Objective Evaluation Method for Simulated Visual Scenes - Preliminary Analysis," NAVTRAEQUIPCEN TN-47, August 1976.

32. Borough, H. C.; Fallis, R. F.; Warnock, R. H.; and Britt, J. H.: "Quantitative Determination of Image Quality," Boeing Company Report D2-114058-1, May 1967.

33. Klingberg, C. S.; Elsworth, C. S.; and Filleau, C. R.: "Image Quality and Detection Performance of Military Photo Interpreters," Boeing Company Report D162-10323-1, September 1970.

34. Ewart, Ronald B.; Harshbarger, John H.: "Measurement of Flight Simulator Visual System Performance," Journal of the Society of Photo-Optical Instrumentation Engineers (SPIE) Volume 59 (1975) Simulators and Simulation

35. MIL-STD-1558, Military Standard - "Six-Degree-of-Freedom Motion System Requirements for Aircrewmember Training Simulators," February 1974.

36. Anon: MIL-D-8708, Military Specifications; Demonstration Requirements for Airplanes.

37. Grove, Randall D., and Mayhew, Stanley C.: "A Real-Time Digital Program for Estimating Aircraft Stability and Control Parameters from Flight Test Data by using the Maximum Likelihood Method," NASA TMX-2788, December 1973.

APPENDIX A

RECOMMENDATION FOR SPECIFICATION FOR FUNCTIONAL TEST REQUIREMENTS FOR EVALUATING FLYING QUALITIES AND PERFORMANCE OF FIXED WING AIRCRAFT WEAPON SYSTEM TRAINERS AND OPERATIONAL FLIGHT TRAINERS

RECOMMENDATION FOR SPECIFICATION FOR FUNCTIONAL TEST REQUIREMENTS FOR EVALUATING FLYING QUALITIES AND PERFORMANCE OF FIXED WING AIRCRAFT WEAPON SYSTEM TRAINERS AND OPERATIONAL FLIGHT TRAINERS

1. SCOPE

1.1 This specification contains the requirements to be fulfilled in evaluating the aerodynamic flying qualities and performance, and engine performance of fixed wing aircraft Weapon System Trainers (WST) and Operational Flight Trainers (OFT). The requirements consist of tests, test conditions, test configurations, test methods, and tolerances to be met.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on the date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Military

MIL-D-8708	Demonstration Requirements for Aircraft
MIL-F-8785	Flying Qualities of Piloted Airplanes
MIL-T-23991	Training Devices, Military; General Specification for
MIL-T-29032	Trainers, Flight; General Specification for

PUBLICATIONS

U. S. Naval Air Test Center

FTM-103	Fixed Wing Stability and Control Theory and Flight Test Techniques
FTM-104	Fixed Wing Performance - Theory and Flight Test Techniques

USAF Aerospace Research Pilot School

FTC-TIH-64-2004	Handbook of Stability and Control

(Copies of specifications, standards, publications and drawings required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the Procuring Contracting Officer.)

2.2 Other publications.- The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply:

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

ASA Y10.7	Letter Symbols for Aeronautical Sciences

(Application for copies should be addressed to the American Society of Mechanical Engineers, 345 E. 47th Street, New York, NY 10017.)

DEPARTMENT OF LABOR

OSHA Standard 1910.96	Ionizing Radiation

(Application for copies should be addressed to the Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402.)

(Technical Society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

3. REQUIREMENTS

3.1 Application.- The functional test requirements specified herein cover the tests to be performed, the test configurations, the test procedures, and the data which shall be recorded. The requirements provide a uniform method for direct comparison of the flight performance, flying qualities, and engine performance of the WST or OFT with the test results of the aircraft.

3.1.1 Prototype trainers.- Tests conducted on prototype trainers shall consist of all tests specified in 4, and such additional functional tests which may be required in accordance with the detail trainer specification to demonstrate conformance with the test results of the aircraft.

3.1.2 Production trainers.- For production trainers, tests shall be conducted from 4 to demonstrate conformance to the test results of the prototype trainer. The areas of 4 to be conducted are designated by an asterisk (*). Additional functional testing may be required in accordance with the detail trainer specification.

3.2 Performance of tests.- Tests specified herein shall be conducted by the contractor, subsequent to completion of the quality assurance provisions

of MIL-T-23991, and prior to the NAVTRAEQUIPCEN Representative's test and acceptance program. All required tests shall be validated and certified by a Government inspector. This certification shall consist of initialing all original data sheets used in the tests. A copy of these data sheets shall be provided to the Government inspector by the contractor. When changes or recalibration for alignment, equipment failure or adjustment purposes are made during the test programs, such changes shall be recorded on the data sheets. Tests which may have been conducted prior to such adjustments shall be repeated unless conclusive proof can be provided that such adjustments have not invalidated the recorded test data up to the time of such adjustments. Upon the successful completion of the tests specified, the trainer shall be made available to the NAVTRAEQUIPCEN Technical Representative for his test and acceptance program.

3.3 <u>Test equipment, programs and instrumentation.</u>The contractor shall supply all test equipment, programs and instrumentation necessary to conduct the various tests accurately and expeditiously. Test equipment and programs shall include, but not be limited to: means for introducing pulse, step, and sinusoidal disturbances of simulated flight control surface deflections, equipment for measuring time, control forces and deflections, and equipment for real time data recording of up to twelve flight variables simultaneously. Additional programming required shall provide the capability to command straight and level flight at predetermined flight conditions. The capability shall exist to vary airspeed while automatically maintaining trimmed flight. The capability to individually or collectively freeze roll, pitch, yaw, X, Y, and Z shall be provided. All such equipment and programs shall be checked or calibrated within one month prior to conducting the test program. A list of all test equipment and conversion data shall be included in the Test Procedures and Results Report.

3.4 <u>Reporting of results</u>.- Test results shall be prepared in accordance with the following:

3.4.1 <u>Test procedure format</u>.-

(a) Title of test - including subparagraph number

(b) Purpose - A statement of what the test is intended to accomplish

(c) Test Method - a statement indicating how the test is to be performed, including calculations, formulae, and conversion factors required to correlate test measurements with specified test criteria. When two or more quantitative readings are required simultaneously, the method of utilizing a plotter or data recording and computer printout shall be described

(d) Test equipment and software test aids required - include test points, setup adjustment, and implementing instructions

(e) Initial conditions - include simulator configuration, loading, altitude, speed, gross weight, center of gravity, and setting of controls and the like prior to conducting testing

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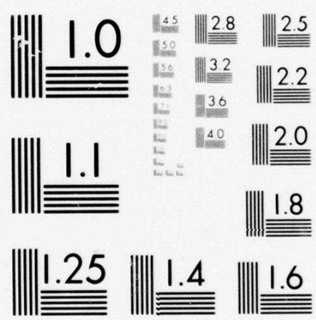

MICROCOPY RESOLUTION TEST CHART

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(f) Additional requirements - discuss personnel required to conduct the testing, potential hazards to personnel performing the testing, and the like

(g) Test procedures - detailed step-by-step procedures are required

(h) Reference aircraft test data to which comparison is being made.

3.4.2 Tabular format.- The tabular format of test procedures shall use the following headings:

(a) Test item number

(b) Specification reference - test identification

(c) NATOPS flight handbook or other aircraft reference data

(d) Control action

(e) Expected results including tolerances

(f) Results/remarks.

3.4.3 Test data.- The simulator test data shall be presented as curves, tables, or data entries as specified herein.

3.4.4 Reference data.- Simulator test criteria shall be limited to measured test data as recorded from testing of the reference aircraft.

3.4.5 Tolerances.- All tolerances shall be in accordance with the detail specification and MIL-T-29032. The simulator performance shall equal the test criteria of 3.4.4 plus or minus the specified tolerances.

3.4.6 Test grouping.- In this specification, tests have been grouped into static or steady state tests and dynamic or transient tests, for convenience. The tests as performed by the contractor shall be sequenced in such a manner as to prevent redundancies of tests and to permit a maximum amount of data acquisition in a minimum of time. For example, engine steady state testing and longitudinal trim testing may be simultaneously conducted.

3.5 Revision of test requirements.- Requests for changes (revisions, deviations, or additions), to requirements specified herein, deemed necessary to completely verify the simulation of the aircraft shall be presented at the time when the proposed criteria reports are submitted for approval. All such requests shall be substantiated by pertinent facts, in writing, to the Contracting Officer for approval.

4. INSPECTIONS AND TEST PROCEDURES

4.1 Responsibility for inspection.- Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. The Government reserves the right to perform any additional inspections necessary to assure that supplies and services conform to contracted requirements.

4.2 Conditions and configurations.- MIL-D-8708 and MIL-F-8785 specify demonstration requirements for aircraft in general. In the preparation of the flight trainer test requirements, specific conditions and configurations required in the aircraft test specification addendum to MIL-D-8708 shall be utilized to facilitate correlation between trainer and aircraft demonstration results. Exceptions to the use of aircraft test data shall be identified and justified by the contractor 90 days prior to test guide submission. Preferred conditions for testing to conditions other than those of the addendum to MIL-D-8708 are shown in table A1.

4.2.1 Terms and symbols.- Terms used herein and in reporting results, other than those defined within the specific requirement, shall be in accordance with 6.2. The symbols used herein and in reporting results, other than those defined within the specific requirement, shall be in accordance with the American Standards Association Y10.7, "Letter Symbols for Aeronautical Science."

4.2.2 Testing method references.- Testing methodologies may vary somewhat from simulator to simulator depending upon the type of aircraft being simulated. Any procedure normally used in aircraft flight testing may be used in simulator testing; however, when preferred methods exist, they are shown in table I and may be found in the following testing references:

(a) FTM No. 103, "Fixed Wing Stability and Control Theory and Flight Test Techniques", U.S. Naval Test Pilot's School Flight Test Manual, August 1969

(b) FTM No. 104, "Fixed Wing Performance - Theory and Flight Test Techniques", U.S. Naval Test Pilot's School Flight Test Manual, July 1972

(c) FTC-TIH-64-2004, "Handbook of Stability and Control", U.S. Air Force Research Pilot's School.

Computer aided testing may be used for simulator testing provided the results may be referenced to aircraft reference data.

4.3 Required testing program.- The following areas of flying qualities and performance and engine performance shall be tested. Table A1 specifies the tests, conditions (if not covered in MIL-D-8708 addenda) and recommended testing techniques when they exist.

4.3.1 Preliminary tests.-

* 4.3.1.1 Control systems.- Mechanical characteristics of all trim and control systems. Determine:

(a) Breakout and friction forces

(b) Freeplay

(c) Control centering

(d) Dynamic properties - damping and natural frequency

(e) Configuration dimensionality

(f) Control force versus control deflection

(g) Control deflection versus trim actuation (statics)

(h) Surface deflection versus control deflection

(i) Control deflection parameterized against actuation of appurtenances - speedbrakes, wingflaps, radome, etc.

(j) Trim characteristics - control position as a function of trim actuation (dynamics, rough spots, backlash, etc.)

(k) Time histories of control deflection and force, surface deflection and trim actuation.

* 4.3.1.2 <u>Weight and balance</u>.- Weight and balance testing shall be completed prior to flying quality or performance testing. Determine:

Center of gravity versus gross weight.

4.3.2 <u>Flying qualities</u>.-

4.3.2.1 <u>Longitudinal stability and control</u>.-

* 4.3.2.1.1 <u>Steady state trim points</u>.-

(a) Angle of attack versus trim airspeed (IAS or mach)

(b) Control deflection versus trim airspeed (IAS or mach)

(c) Trim surface deflection versus trim airspeed (IAS or mach)

(d) Optimum approach airspeed versus gross weight

(e) Optimum approach airspeed trim surface incidence versus gross weight.

* 4.3.2.1.2 <u>Longitudinal trim changes due to changes in thrust and activation of appurtenances</u>.-

(a) Change in control position, control force, pitch angle, angle of attack, altitude, and air speed required to maintain the conditions specified in table II following individual activation of all appurtenances

(b) Changes in control position, control force, pitch angle, angle of attack, altitude, and airspeed required to maintain level flight following activation of all appurtenances not mentioned in table II; for example, wing sweep changes, retractable radomes, expendable external fuel tanks and stores, etc.

* 4.3.2.1.3 Static longitudinal stability.- Determine:

(a) Control deflection versus airspeed (IAS or mach)

(b) Control force versus airspeed (IAS or mach)

(c) Angle of attack versus airspeed (IAS or mach)

(d) Rate of climb versus airspeed (PA configuration only, IAS).

* 4.3.2.1.4 Maneuvering stability.- Determine:

(a) Control deflection versus normal acceleration

(b) Control force versus normal acceleration

(c) Angle of attack versus normal acceleration.

* 4.3.2.1.5 Dynamic longitudinal stability.- Determine:

(a) Short period frequency versus airspeed (IAS or mach)

(b) Short period damping versus airspeed (IAS or mach)

(c) Phugoid frequency versus airspeed (IAS or mach)

(d) Phugoid damping versus airspeed (IAS or mach)

(e) Time phase relationships of control deflection, control force, surface deflection, pitch angle and rate, angle of attack, normal acceleration, rate of climb and airspeed (or mach). (Time phase testing for medium CR and PA runs only). Time to first peak

(f) Short period at normal accelerations greater than 1 for medium GW, medium altitude runs only versus normal acceleration.

4.3.2.2 Lateral-directional stability and control.-

* 4.3.2.2.1 Static lateral-directional stability.-

Rudder control deflection and force, aileron control deflection and force, roll angle and longitudinal control deflection versus sideslip angle.

* 4.3.2.2.2 Dynamic lateral-directional stability.-

(a) Dutch roll period and damping versus airspeed (IAS or mach)

(b) Spiral stability (control deflection, heading and bank angle versus time)

(c) Roll response (control deflection, heading, roll angle, and rate versus time for full and partial deflection. Partial inputs shall be less than 10 percent of full deflection)

(d) Time phase relationships of control deflection, control force, surface deflection, roll angle, roll rate, sideslip angle, and heading angle

(e) Roll to yaw ratio.

4.3.2.3 Engine out flying qualities.-

(a) Minimum control ground speed

(b) Minimum control airspeed (static and dynamic)

(c) Time phase sequences during engine failure (plots of power lever angle, blade angle, roll, pitch and yaw angles, longitudinal, lateral and directional control deflection versus time)

(d) Plots of lateral and directional control deflection and force, sideslip, and pitch angles versus roll angle. Record power setting.

4.3.2.4 Ground handling characteristics.-

(a) Nose gear steering effectiveness

Plots of heading versus time parameterized against percent application of nose gear steering and taxi speed

(b) Brake effectiveness

(1) Plots of heading versus time parameterized against amount of asymmetrical brake application

(2) Plots of ground speed versus time parameterized against symmetrical brake application

(c) Aileron effectiveness speed

(d) Rudder effectiveness speed.

4.3.3 Performance.-

4.3.3.1 Airframe properties.-

4.3.3.1.1 Takeoff characteristics.-

* (a) Nosewheel liftoff speed versus gross weight

(b) Time to reach nosewheel liftoff speed versus gross weight

(c) Attitude of takeoff (plots of airspeed, rate of climb, longitudinal, lateral and directional control deflection, pitch angle and angle of attack versus time)

* (d) Technique of takeoff (qualitative)

(e) Crosswind takeoff (qualitative)

* (f) Catapult launch (qualitative).

4.3.3.1.2 Inflight characteristics.-

* (a) Level acceleration

Plots of airspeed (IAS or mach) versus time

* (b) Level deceleration

Plots of airspeed (IAS or mach) versus time with and without speed brakes

(c) Maximum speed per configuration for level flight

* (d) Climb performance

(1) Plots of altitude versus time

(2) Plots of rate of climb versus airspeed (IAS or mach)

(e) Stall characteristics

(1) One g stalls - stall angle of attack, plot stall speed versus gross weight

(2) Accelerated stalls - stall angle of attack and the product of normal acceleration times gross weight (η x GW) versus Mach or airspeed

(3) Buffet boundary - plot angle of attack and (η x GW) versus Mach or airspeed for onset and limit buffet for one g and accelerated stalls

(f) Stall and spin effects

Plots of angle of attack, speed, heading angle and rate, sideslip angle, pitch angle and rate, roll angle and rate, and altitude versus time during the stalls and spins.

4.3.3.1.3 Landing characteristics.-

(a) Ground effects

(1) Ground effects hold off speed (IAS)

(2) Qualitative evaluation of pitch and rate of climb (descent) control

(3) Plot longitudinal control deflection versus angle of attack

* (b) Landing time histories and aerodynamic braking

(1) Plots of angle of attack, altitude, rate of climb, airspeed/ groundspeed, pitch angle, longitudinal control deflection, and spoiler deflection versus time during normal landings

* (c) Drag chute operation (if applicable) - qualitative evaluation

* (d) Tail hook operation (if applicable) - qualitative evaluation

* (e) Spoiler operation (if applicable) - qualitative evaluation.

4.3.3.1.4 <u>Engine-out performance</u>.-

(a) Acceleration

Plots of airspeed (IAS or mach) versus time

(b) Climb performance

(1) Altitude versus time

(2) Rate of climb versus airspeed.

4.3.3.2 <u>Engine</u>.-

4.3.3.2.1 <u>Engine statics</u>.- For standard day and standard day plus or minus 50°F determine:

* (a) Thrust (or power for propeller driven aircraft) available

All pertinent engine variables versus mach (or IAS) parameterized against altitude and power lever position

* (b) Thrust required - stabilized level flight

All pertinent engine variables versus mach (or IAS) parameterized against altitude for stabilized level flight

* (c) Pertinent engine variables as a function of power lever angle at sea level, mach equal zero

(d) Afterburner envelope - ignition possible envelope and blowout envelope

(e) Air start envelope (mach altitude plane)

(f) Windmilling rpm versus mach (or IAS) parameterized against altitude.

4.3.3.2.2 Engine dynamics.-

(a) Starting characteristics

Plot all pertinent engine variables versus time for all starting methods (normal and emergency)

* (b) Acceleration/deceleration characteristics for large (full) and and small (less than 10 percent of full throw) power lever excursions, particularly about the optimum approach speed power settings

Plots of all pertinent engine variables versus time

(c) Power down characteristics

Plots of all pertinent engine variables versus time.

5. PACKAGING. This section is not applicable.

6. NOTES

6.1 Intended use.- This specification is intended to provide the general flying qualities and performance test requirements for aircraft flight trainers and to serve as a basis for the preparation of the test procedure and test results reports which can be directly compared with appropriate aircraft test results.

6.2 Definitions.- Terms and symbols used throughout this specification are defined as follows:

6.2.1 General.-

(a) Altitude.- All altitudes specified herein are pressure altitudes. Several altitudes used are:

(1) h_{max} - Maximum service altitude. The maximum service altitude for a given speed is the maximum altitude at which a rate of climb of 100 feet per minute can be maintained in unaccelerated flight with MAT

(2) h_{mid} - 1/2 h_{max}

(3) $h_{o_{max}}$ - Maximum operational altitude

(4) $h_{o_{min}}$ - Minimum operational altitude

(5) MSL - Mean Sea Level

(b) Appurtenance - Any pilot activated device which disrupts the equilibrium flight of the aircraft. For example: Landing gear, wing flaps, speed brakes, extendable radomes, MAD booms, swing wings and the like

(c) c.g. - Aircraft center of gravity

(d) Configurations - Simulated aircraft components such as landing gear, wing flaps, cowl flaps, oil radiator flaps and shutters, controllable wing slots, gun turrets, blast tube covers, etc., will be in their normal settings for the particular configurations. For aircraft equipped with external droppable stores, stability and control requirements will be met with stores both attached and removed in configurations P, CR, L, PA, and TO

(1) Configuration CR, Cruise - Power for level flight at trim speed, flaps in cruise position, and gear up

(2) Configuration L, Landing - Idle power, flaps and gear down, or other high lift devices at landing setting

(3) Configuration P, Power-on Clean - Normal rated power, flaps and gear up

(4) Configuration PA, Power Approach - Power for level flight at $1.15V_S(L)$ or normal approach speed, whichever is lower, flaps and gear down, other high lift devices in normal approach position

(5) Configuration TO, Take-off - Take-off power, high lift devices and gear in normal take-off position

(e) Control parameters.-

(1) Controls - The stick or wheel and rudder pedals manipulated by the pilot to produce pitching, rolling, and yawing moments respectively; the cockpit controls

(2) Longitudinal control force - Component of applied force, exerted by the pilot on the cockpit control, in or parallel to the plane of symmetry, acting at the center of the stick grip or wheel in a direction perpendicular to a line between the center of the stick grip or wheel and the stick or control column pivot

(3) Lateral control force - For a stick control, the component of control force exerted by the pilot in a plane perpendicular to the plane of symmetry, acting at the center of the stick grip in a direction perpendicular to a line between the center of the stick grip and the stick pivot. For a wheel control, the total moment applied by the pilot about the wheel axis in the plane of the wheel, divided by the average radius from the wheel pivot to the pilot's grip

(4) Directional pedal force - Difference of push-force components of forces exerted by the pilot on the rudder pedals, lying in planes parallel to the plane of symmetry, measured

perpendicular to the pedals at the normal point of application of the pilot's instep on the respective rudder pedals

(5) Control surface - A device such as an external surface which is positioned by a cockpit control or stability augmentation to produce aerodynamic or jet-reaction type forces for controlling the attitude of the airplane. As used in this specification the elevator surface, aileron surface, and rudder surface are the control surfaces or devices which are controlled by the stick or wheel and rudder pedals, and automatically by stability augmentation system

(f) GW - Gross weight

(g) N - Normal acceleration

(1) n(+), n(-) - For a given altitude, the upper and lower boundaries of n in the V-n diagrams depicting the Service Flight Envelope

(2) $n_{o_{max}}$, $n_{o_{min}}$ - Maximum and minimum Operational load factors

(3) $n_o(+)$, $n_o(-)$ For a given altitude, the upper and lower boundaries of n in the V-n diagrams depicting the Operational Flight Envelope

(h) Operational Flight Envelopes.- The Operational Flight Envelopes define the boundaries in terms of speed, altitude, and load factor within which the airplane must be capable of operating in order to accomplish its missions. Envelopes for each applicable Flight Phase shall be established with the guidance and approval of the procuring activity

(i) Pertinent engine variables.- Those parameters that are discernible to the pilot and also vary with engine controls position, Mach number, altitude or governing apparatus such as RPM and tail pipe temperature limiting devices. Sample pertinent engine variables might include:

Jet	Turboprop	Reciprocating
RPM (Compressor, turbine, etc.)	RPM (Turbine, propeller, etc.)	RPM (Engine, propeller, etc.)
Fuel flow	Fuel flow	Cylinder head temperature
Nozzle area	Indicated shaft horse-power	Mixture control
Exhaust gas temp.	Engine pressure ratio	Propeller control

Turbine inlet temp.	Torque	Manifold pressure
Power lever angle Oil temperature Oil pressure	Turbine inlet temp.	Oil temperature Oil pressure
Thrust	Exhaust gas temp.	Power lever angle
Pressure ratio	Power lever angle Thrust	
Turbine inlet temperature Fuel pressure		

The exact variables will depend on the engine being simulated

(j) Speed - Airspeed or ground speed. Where appropriate, air speed may be replaced by Mach

(1) V_{max} - Maximum service speed - The maximum service speed, V_{max} or M_{max}, for each altitude is the lowest of:

a. The maximum permissible speed

b. A speed which is a safe margin below the speed at which intolerable buffet or structural vibration is encountered

c. The maximum airspeed at MAT, for each altitude, for dives (at all angles) from V_{MAT} at all altitudes, from which recovery can be made at 2,000 feet above MSL or higher without penetrating a safe margin from loss of control, other dangerous behavior, or intolerable buffet, and without exceeding structural limits

(2) V_{min} - Minimum service speed - The minimum service speed, V_{min} or M_{min} , for each altitude is the highest of:

a. 1.1. V_S

b. V_S + 10 knots equivalent airspeed

c. The speed below which full airplane-nose-up elevator control power and trim are insufficient to maintain straight, steady flight

d. The lowest speed at which level flight can be maintained with MRT

e. A speed limited by reduced visibility or an extreme pitch attitude that would result in the tail or aft fuselage contacting the ground

(3) Minimum permissible speed other than stall - For some airplanes, considerations other than maximum lift determine the minimum permissible speed in 1g flight (e.g., ability to perform altitude corrections, excessive sinking speed, ability to execute a wave-off (go-around), etc.). In such cases, an arbitrary angle-of-attack limit, or similar minimum speed and maximum load factor limits, shall be established for the Permissible Flight Envelope, subject to the approval of the procuring activity. This defined minimum permissible speed shall be used as V_S in all applicable requirements

(4) V_{NRT} - High speed, level flight, normal rated thrust

(5) V_{MRT} - High speed, level flight, military rated thrust

(6) V_{MAT} - High speed, level flight, maximum augmented thrust

(7) $V_{o_{max}}$ - Maximum operational speed

(8) $V_{o_{min}}$ - Minimum operational speed

(9) V_S - Stall speed (equivalent airspeed), at 1g normal to the flight path, defined as the highest of:

a. Speed for steady straight flight at $C_{L_{max}}$, the first local maximum of the curve of lift coefficient (L/qS) vs. angle of attack which occurs as C_L is increased from zero

b. Speed at which abrupt uncontrollable pitching, rolling or yawing occurs, i.e., loss of control about a single axis

c. Speed at which intolerable buffet or structural vibration is encountered

(10) $V_S(X)$, $V_{min}(X)$, $V_{max}(X)$ - Shorthand notation for the speeds V_S, V_{min}, V_{max} for a given configuration, weight, center-of-gravity position, and external stores combination associated with Flight Phase X. For example, the designation $V_{max}(TO)$ (for the weight, center-of-gravity and external stores combination under consideration) is V_{max} for the configuration associated with the takeoff Flight Phase

(k) Thrust and power.-

(1) Thrust and power - For propeller-driven airplanes, the word "thrust" shall be replaced by the word "power" throughout the specification

(2) TLF - Thrust for level flight

(3) NRT - Normal rated thrust, which is the maximum thrust at which the engine can be operated continuously

(4) MRT - Military rated thrust, which is the maximum thrust at which the engine can be operated for a specified period

(5) MAT - Maximum augmented thrust: maximum thrust, augmented by all means available for the Flight Phase

(6) Takeoff thrust - Maximum thrust available for takeoff.

TABLE A1. FLYING QUALITY AND PERFORMANCE TESTING

Paragraph	Tests	Configuration	Altitude	Airspeed KEAS or MACH as appropriate	Average Gross Weight	Average CG Position	Power Setting	Load Factor	Recommended Technique Ref/Page
4.3.1.1	Mechanical characteristics of control systems	Boost on and Boost off. CR, PA, for reversible systems	MSL for irreversible systems. See MIL-D-8708 Add. for reversible system	AR (As Required)	Light with lowest rolling and yawing moments of inertia	Fwd	AR	1	A/IV 59
4.3.2.1.1	Steady State trim points	CR	h_{mid} $h_{o_{max}}$	1. $2V_S$(CR) To V_{MAT}	Normal CR	Normal CR	TLF	1	AR
		PA	$h_{o_{min}}$	1. $2V_S$(PA) To flap limit speed	Allowable Landing Weight Range	AR			
4.3.2.1.2	Longitudinal trim changes due to changes in thrust and activation of appurtenances	See Table II	See Table II	See Table II	Normal (PA) TO, CR as required	AR	See Table II TLF for items not mentioned in Table II	AR	AR
4.3.2.1.3	Static longitudinal stability	CR	h_{mid}	V_{min} to V_{max}	AR	Most AFT	TLF	1	Stabilize point A/IV 68
		PA, L	$h_{o_{min}}$	V_{min} to V_{max}	AR	Most FWD			
4.3.2.1.4	Maneuvering Stability	P, CR	$h_{o_{min}}$	$V_{max}/2$	Heaviest	Most FWD	AR	n(-) to n(+)	Steady turns and steady push-overs A/IV 158
			h_{mid}	$V_{max}/3$	Lightest	Most AFT			
			h_{mid}	3/4 V_{max}	Medium	Medium			
		PA	$h_{o_{min}}$	1.4 V_S(PA)	Normal (PA)	Normal (PA)			

TABLE A1. FLYING QUALITY AND PERFORMANCE TESTING (Continued)

Paragraph	Tests	Configuration	Altitude	Airspeed KEAS or MACH as appropriate	Average Gross Weight	Average CG Position	Power Setting	Load Factor	Recommended Technique Ref/Page
4.3.2.1.5	Dynamic longitudinal stability	SAS both activated and de-activated CR, P, PA, TO, L	h_{omin} h_{mid} h_{omax}	V_{min} to V_{max}	Med (CR) Normal (PA)	Fwd AR	AR	AR to n(+)	Doublet A/IV 173 For short period A/IV 73 also computer input doublet(s) and phugoid excitation
4.3.2.2.1	Static lateral-directional stability	CR, P	h_{omax} h_{mid}	V_{min} to V_{max}	Lightest CR	Normal CR	AR	1	A/V 93
		PA	h_{omin}	V_{min} to V_{max}	Normal (PA)	Normal (PA)			
4.3.2.2.2.	Dynamic lateral-directional stability	P	h_{mid}	V_{min} to V_{max}	Greatest roll moment of inertia	Mid		1 and $N_o(+)$	Rudder pulsing A/V 109,
		CR,	h_{mid}	V_{min} to V_{max}	Greatest yaw moment of inertia	Mid	TLF		A/V 98, and computer-controlled excitation of the Dutch roll
		CR (Roll only)	h_{mid}	V_{min} to V_{max}	Smallest roll moment of inertia	Mid			
		PA	h_{omin}	$1.2V_S(PA)$	Normal (PA)	Normal (PA)			
4.3.2.3	Engine out	P,	h_{omin}	$1.4V_S(CR)$	Lightest	Aft	AR with failures	1	C/9.7 A/V 239 C/9.4
	Flying qualities	TO	h_{omin}	$1.2V_S(TO)$	Heavy	Aft			
		Control boost on & off. Port outboard and inboard engines failed separately & jointly. Starboard outboard engine failed separately.							

TABLE A1. FLYING QUALITY AND PERFORMANCE TESTING (Continued)

Paragraph	Tests	Configuration	Altitude	Airspeed KEAS or MACH as appropriate	Average Gross Weight	Average CG Position	Power Setting	Load Factor	Recommended Technique Ref/Page
4.3.2.4	Ground handling characteristics	TO	MSL	AR	Heavy TO	Aft	AR	1	Minimum aileron & rudder speeds A/V 260
4.3.3.1.1	Takeoff characteristics	TO	MSL	AR	Varied up to Heaviest with CG requirement	Critical forward and Aft for nose wheel aircraft	MRT and MAT	AR	Minimum takeoffs A/IV 210 Normal take-offs for NATOPS technique
4.3.3.1.2	Inflight characteristics	CR PA	.8 $h_{o_{max}}$ h_{mid} $h_{o_{min}}$	$1.2V_S$(CR) to V_{MAT} $1.2V_S$(PA) to flap limit speed	Medium CR Medium PA	Normal CR Normal PA	MRT, MAT Idle MRT, MAT *Idle*	1 1	acc. a.B/VI 10 c.NATOPS *schedule* e.stalls B/V 7 f.spins A/III 11
4.3.3.1.3	Landing Characteristics	L	$h_{o_{min}}$	$1.2V_S$(PA)	Normal Landing Weight	Maximum forward	Approach	1	1.Ground effects A/IV 207
4.3.3.1.4	Engine-out performance	CR PA Port out- and inboard engines failed separately and jointly.	h_{mid} $h_{o_{min}}$	$1.2V_S$(CR) to V_{MAT} $1.2V_S$(PA) to flap limit speed	Medium CR Medium PA	Normal CR Normal PA	AR	1	

TABLE A1. FLYING QUALITY AND PERFORMANCE TESTING (Continued)

Paragraph	Tests	Configuration	Altitude	Airspeed KEAS or MACH as appropriate	Average Gross Weight	Average CG Position	Power Setting	Load Factor	Recommended Technique Ref/Page
4.3.3.2.1	Engine statics	CR, PA All conditions of bleed air	$h_{o_{max}}$ h_{mid} $h_{o_{min}}$	0 to V_{MAT}	Medium CR	Normal CR	Variable	1	
4.3.3.2.2	Engine dynamics	TO All conditions of bleed air	Same as Engine Statics						

TABLE A2. Pitch Trim Change Conditions

	Flight Phase	Initial Trim Condition					Configuration Change	Parameter to be held constant
		Altitude	Speed	Landing Gear	High-lift Devices & Wing Flaps	Thrust		
1	Approach	$h_{o_{min}}$	Normal pattern entry speed	Up	Up	TLF	Gear down	Altitude and airspeed*
2				Up	Up	TLF	Gear down	Altitude
3				Down	Up	TLF	Extend high-lift devices and wing flaps	Altitude and airspeed*
4				Down	Up	TLF	Extend high-lift devices and wing flaps	Altitude
5				Down	Down	TLF	Idle thrust	Airspeed
6			$V_{o_{min}}$	Down	Down	TLF	Extend approach drag device	Airspeed
7				Down	Down	TLF	Takeoff thrust	Airspeed
8	Approach		$V_{o_{min}}$	Down	Down	TLF	Takeoff thrust plus normal clean-up for wave-off (go-around)	Airspeed
9	Takeoff			Down	Take-off	Take-off thrust	Gear up	Pitch attitude
10			Minimum flap-retract speed	Up	Take-off	Take-off thrust	Retract high-lift devices and wing flaps	Airspeed
11	Cruise and air-to-air combat	$h_{o_{min}}$ and $h_{o_{max}}$	Speed for level flight	Up	Up	MRT	Idle thrust	Pitch attitude
12				Up	Up	MRT	Actuate deceleration device	
13				Up	Up	MRT	Maximum augmented thrust	
14			Speed for best range	Up	Up	TLF	Actuate deceleration device	

*Throttle setting may be changed during the maneuver

Notes: - Auxiliary drag devices are initially retracted, and all details of configuration not specifically mentioned are normal for the Flight Phase.

- If power reduction is permitted in meeting the deceleration requirements established for the mission, actuation of the deceleration device in #12 and #14 shall be accompanied by the allowable power reduction.

APPENDIX B

RECOMMENDATION FOR SPECIFICATION FOR FUNCTIONAL TEST REQUIREMENTS FOR EVALUATING COCKPIT MOTION SYSTEMS AS USED WITH AIRCRAFT WEAPON SYSTEM TRAINERS AND OPERATIONAL FLIGHT TRAINERS

RECOMMENDATION FOR SPECIFICATION FOR FUNCTIONAL TEST REQUIREMENTS FOR EVALUATING COCKPIT MOTION SYSTEMS AS USED WITH AIRCRAFT WEAPON SYSTEM TRAINERS AND OPERATIONAL FLIGHT TRAINERS

1. SCOPE

1.1 This specification contains the requirements to be fulfilled in evaluating the engineering performance of cockpit motion systems as used with Weapon System Trainers (WST) and Operational Flight Trainers (OFT). The requirements consist of tests, test conditions, test configurations, test methods, and tolerances to be met.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on the date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Military

MIL-T-23991	Training Devices, Military; General Specification for

STANDARDS

Military

MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment, and Facilities

(Copies of specifications, standards, publications, and drawings required by suppliers in connection with specific procurement functions shall be obtained from the procuring activity or as directed by the Contracting Officer.)

3. REQUIREMENTS

3.1 Application.- The functional test requirements specified herein cover the tests to be performed, the test configurations, the test procedures, and the data which shall be provided. The requirements provide a uniform method for direct comparison of the cockpit motion system with the test criteria data.

3.1.1 Prototype trainers.- Tests conducted on prototype trainers shall consist of all tests specified herein, and such additional functional tests which may be required in accordance with the detail trainer specification to demonstrate conformance with the reference test criteria.

3.1.2 Production trainers.- For production trainers, tests shall be conducted from those specified herein to demonstrate conformance to the test results of the prototype trainer. The areas of the tests to be conducted are designated by an asterisk (*). Additional functional testing may be required in accordance with the detail specification.

3.2 Performance of tests.- Tests specified herein shall be conducted by the contractor, subsequent to completion of the quality assurance provisions of MIL-T-23991, and prior to the Contracting Officer's daily authorized representative's test and acceptance program. All required tests shall be validated and certified by a Government inspector. This certification shall consist of initialing all original data sheets used in the tests. A copy of these data sheets shall be provided to the Government inspector by the contractor. When changes or recalibration for alignment, equipment failure, or adjustment purposes are made during the test programs, such changes shall be recorded on the data sheets. Tests which may have been conducted prior to such adjustments shall be repeated unless conclusive proof can be provided that such adjustments have not invalidated the recorded test data up to the time of such adjustments. Upon the successful completion of the tests specified, the trainer shall be made available to the Contracting Officer's authorized technical representative for his test and acceptance program.

3.3 Test equipment, programs, and instrumentation.- The contractor shall supply all test equipment, programs, and instrumentation necessary to conduct the various tests accurately and expeditiously. The equipment and programs shall include, but not be limited to:

(a) Means for introducing pulse, step, ramp, and sinusoidal disturbances of simulated flight control surfaces and individual and collective cockpit motion axes

(b) Equipment for measuring and recording time, control deflections, linear and angular excursions, rates and accelerations, commands and responses of the motion base. The accelerometers and rate gyros shall be mounted as near the trainee's head position as practical or shall be suitably transformed by software manipulation.

(c) Equipment for real-time data recording of up to 25 variables. Magnetic tape or disc digital data recording are permissible provided the capability to record at the highest iteration rates used is provided. Strip chart recording may be used if 1/2 percent accuracy is available up to 2 Hz.

(d) The capability to command straight and level flight at predetermined flight conditions

(e) The capability to individually or collectively freeze roll, pitch, yaw, x, y, and z axes.

All such equipment and programs shall be checked or calibrated within one month prior to conducting the test program. A list of all test equipment and conversion data shall be included in the Government-approved Test Procedures and Results Report.

3.4 Reporting of results.- Test results shall be prepared in accordance with the following:

3.4.1 Test procedure format.-

(a) Title of test - including subparagraph number

(b) Purpose - a statement of what the test is intended to accomplish

(c) Test method - a statement indicating how the test is to be performed, including calculations, formulae, and conversion factors required to correlate test results with specified test criteria. When two or more quantitative readings are required simultaneously, the method of utilizing a plotter or data recording and computer printout shall be described

(d) Test equipment and software test aids required - include test points, set-up adjustments, and implementing instructions

(e) Initial conditions - include simulator configuration loadings, altitude, speed, gross weight, center-of-gravity, setting of controls, and the like prior to conducting testing

(f) Additional requirements - discuss personnel required to conduct the testing, potential hazards to personnel performing the testing, and the like

(g) Test procedures - detailed step-by-step procedures are required

(h) Reference aircraft test data to which comparison is being made superposed with tolerances.

3.4.2 Test data.- The simulator test results data shall be presented as curves, tables, or data entries as specified herein.

3.4.3 Reference data.- Simulator test criteria shall be specified in the detailed trainer specification and herein.

3.4.4 Tolerances.- All tolerances shall be in accordance with the detail specification; the tolerances shall be as specified in tables B1, B2 & B3 if not specified in the detail specification. The simulator performance shall equal test criteria of 3.4.3 within the specified tolerances.

3.4.5 Test grouping.- In this specification, tests have been grouped into static or steady-state tests and dynamic or transient tests, for convenience. The tests as performed by the contractor shall be sequenced in such a manner as to prevent redundancies of tests and to permit a maximum amount of data acquisition in a minimum of time.

3.5 Revision of test requirements.- Requests for changes (revisions, deviations, or additions) to requirements specified herein, deemed necessary to completely verify the performance of the motion platform shall be presented at the time when the simulation of the aircraft proposed criteria reports are submitted for approval. All such requests shall be substantiated by pertinent facts, in writing, to the Contracting Officer for approval.

4. INSPECTIONS AND TEST PROCEDURES

4.1 Responsibility for inspection.- Unless otherwise specified in the contractor or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. The Government reserves the right to perform any additional inspections deemed necessary to assure that supplies and services conform to contracted requirements.

4.2 Conditions and configurations.- Conditions and configurations for cockpit motion system testing are shown herein.

4.2.1 Terms and symbols.- Terms used herein and in reporting results shall be in accordance with 6.2.

4.3 Required testing program.- The following areas of cockpit motion system performance shall be tested using the design payload weight.

4.3.1 System attribute testing.-

4.3.1.1 Hardware Capabilities.- The tests shown in table B1 shall be performed to determine the performance characteristics for each degree of freedom.

4.3.1.2 Hardware dynamic performance.- The tests of table B2 shall be conducted recording the time histories of the excursions, velocities, and accelerations for each degree of freedom.

4.3.1.3 Simulation attributes.- The conditions of table B3 shall be evaluated separately considering (1) the basic aerodynamic response, and (2) the motion platform's response. The motion effects (linear and angular displacements, rates, and accelerations) shall be recorded as time history recordings and collectively plotted with the initiating control action, and the two areas mentioned above. The basic aerodynamic response shall be transferred from the simulated center-of-gravity to the trainee sitting position (at the approximate head position of the trainee) in accordance with MIL-STD-1472 via the appropriate coordinate transformations before comparisons are made. If the accelerometers are not mounted at the trainee station, their outputs shall be appropriately transformed to the trainee station.

4.3.1.4 Miscellaneous tests.- Perform the tests of table B4.

5. PACKAGING. This section is not applicable.

6. NOTES

6.1 Intended use.- This specification is intended to provide the general performance test requirements for testing cockpit motion systems as employed with flight simulators and to serve as a basis for the preparation of the test

procedures and test results reports which can be directly compared with appropriate test criteria.

6.2 Definitions.- Terms and symbols used throughout this specification are defined as follows:

(a) Appurtenance - Any pilot-activated device which disrupts the equilibrium flight of the aircraft. For example: Landing gear, wing flaps, speed brakes, extendable radomes, Magnetic Anomaly Detection (MAD) booms, swing wings, and the like

(b) Configurations - Simulated aircraft components such as landing gear, wing flaps, cowl flaps, oil radiator flaps and shutters, controllable wing slots, gun turrets, blast tube covers, etc., will be in their normal settings for the particular configurations. For aircraft equipped with external droppable fuel tanks, stability and control requirements will be met with stores both attached and removed in configurations P, CR, L, PA, and TO. This statement shall apply also to aircraft equipped with other droppable or removable external stores, except that stores not intended for retention during normal service landings need not be considered in configurations L, PA, and TO. If external fuel tank locations are not symmetrical, the tanks may be empty in configurations L, PA, and TO

(1) Configuration CR, cruise - Power for level flight at approximately the speed for maximum range, flaps in cruise position, and gear up

(2) Configuration L, Landing - Power off, flaps and gear down, or other high lift devices at landing setting

(3) Configuration P, Power-on Clean - Normal rated power, flaps and gear up

(4) Configuration PA, Power Approach - Power for level flight at $1.15V_s(L)$ or normal approach speed, whichever is lower, flaps and gear down, other high lift devices in normal approach position

(5) Configuration TO, Take-off - Take-off power, high lift devices and gear in normal take-off position

(c) Cueing system - Simulation system designed to stimulate the trainees sensory perceptors. Cockpit motion, visual display, g-seat, buffet, and instrument displays are typical cueing systems.

TABLE B1. Cockpit Motion System Testing

SYSTEM TEST	TECHNIQUE OR EQUIPMENT	TOLERANCES RECOMMENDED
* 1. Positional accuracy	Compare response to command	1 percent of full scale deflection
2. Repeatability	Compare response to command for repeated commands when approached from either direction	0.5 percent of initial response
3. Linearity	Command unit deflections throughout full excursion capability	Response to unit commands near full deflection shall be within 2% of the response mid-deflection
* 4. Excursion limits	Command full scale deflections	1 percent
5. Velocity limits	As required	5 percent
6. Acceleration limits	As required	5 percent
* 7. Crosstalk	Vary each degree of freedom individually while monitoring all other degrees of freedom. Repeat for all axes of control loading	Less than 2% of the offending servo amplitude
8. Long term drift	Simultaneously command position 1/2 maximum excursion for all degrees of freedom. Monitor all degrees of freedom for change in 16 hr.	Less than 1% of full scale deflection for each degree of freedom
* 9. Smoothness	Command each degree of freedom with a sinusoid of 10% maximum excursion amplitude and 0.1 Hz frequency	Spurious accelerations shall be less than 0.04g for linear degrees of freedom and $1°/sec^2$ for angular degrees of freedom

CONT'D

TABLE B1. Cockpit Motion System Testing. (Continued)

SYSTEM TEST	TECHNIQUE OR EQUIPMENT	TOLERANCES RECOMMENDED
* 10. Stability	For constant velocity of 0.05 maximum for each degree of freedom and for static neutral position keeping, monitor all of freedom for spurious excursions or instabilities	Instability or spurious accelerations shall be lower than 0.015g for linear degrees of freedom and $1/2°/sec^2$ for angular degrees of freedom
* 11. Synchronization of cueing system responses	Simultaneously record individual axes of motion system with analogous axes of other cueing systems such as visual, g-seat, and instrumentation.	Cueing system response shall occur within 50 msec of each other except for normally delayed responses.

TABLE B2. Cockpit Motion Dynamic Tests.

SYSTEM TEST	TECHNIQUE OR EQUIPMENT	TOLERANCES RECOMMENDED
Dynamic Performance		
a. Frequency Response - Bode Plots	Record amplitude and phase relationship for 1/4 maximum drive commands at frequencies up to 5 Hz for each degree of freedom	The amplitude and phase responses shall be within the following tolerances of the values specified in the detail specification
Phasing	Simultaneously record individual axes of motion system with analogous axes of other cueing systems such as visual, g-seat and instrumentation	Analogous system responses shall occur within 5° of each other
b. Transient Response		
1. Step	1/4 and 1/2 maximum excursion	The lowest natural frequency shall be greater than 5 Hz. Damping shall be 0.6 to critical. Time to 0.632 of response amplitude shall be as specified in the detail specification ± 10%
2. Sinusoid	Zero to maximum amplitude at 1/2 the frequency at which a 10°	Verify smoothness, spurious accelerations shall be less than 0.08g for

Tolerances for a. Frequency Response - Bode Plots:

Frequency	Gain (TOLERANCE)	Max Phase Shift (TOLERANCE)
0.1 → 0.5	± 2dB	15°
0.5 → 1.0	± 2dB	45°
1.0 → 2.0	± 3dB	90°
2.0 → 3.0	± 3dB	120°
3.0 → 5.0	+ 5dB - 8dB	130°

TABLE B2. Cockpit Motion Dynamic Tests. (Continued)

SYSTEM TEST	TECHNIQUE OR EQUIPMENT	TOLERANCES RECOMMENDED
	phase shift occurs	linear degrees of freedom and 2°/ sec^2 angular degrees of freedom.

TABLE B3. Cockpit Motion System Testing.

TEST SIMULATION ATTRIBUTES	TECHNIQUE	COMMENT OR TOLERANCE
Evaluate the effects of the following: * 1. Buffet onset and associated effects of airspeed, normal acceleration, angle of attack, or other appropriate parameters for CR and PA configurations * 2. Landing, takeoff and runway maneuvers PA, TO configurations * 3. Propulsion system. PA, CR configurations * 4. Rough or turbulent air * 5. Actuation of appurtenances such as landing gear, wing flaps, wheel brakes, speed brakes, drague chute, and other aerodynamic lift or drag devices * 6. Release of stores	Record, for all degrees of freedom, cockpit motion response including excursions, velocities, and accelerations. Record all simulated linear and angular accelerations and rates. The longitudinal comparison shall compare longitudinal control input, longitudinal and normal accelerations and pitching attitude, velocity and acceleration of the simulated flight to the cueing provided by the motion platform. Lateral-directional comparisons shall compare lateral and directional control inputs, roll rate and acceleration, yaw rate and acceleration, and lateral acceleration of the simulated airframe responses to the same variables of the motion platform's response	1. Washout accelerations shall be less than 0.04g for linear axes and $2°/sec^2$ for angular degrees of freedom 2. Motion responses shall begin within 50 msec of simulated airframe responses 3. Motion responses shallbe properly oriented with respect to the simulated airframe responses

CONT'D

TABLE B3. Cockpit Motion System Testing. (Continued)

TEST SIMULATION ATTRIBUTES	TECHNIQUE	COMMENT OR TOLERANCE
* 7. Tactical maneuvering effects such as air-to-air or air-to-ground weapon delivery		
* 8. Stall		
9. Spin		
10. Pulse and 10 cycles of sinusoidal control deflections separately for the longitudinal, lateral, and direction axes.		

TABLE B4. Cockpit Motion System Testing.

MISCELLANEOUS TESTS	TECHNIQUE OR EQUIPMENT	COMMENT OR TOLERANCE
* 1. Freeze	Freeze the simulator, record position, velocity, and acceleration	The motion system shall remain in the position it was in when the freeze was initiated
* 2. Crash	Crash the simulator, record position, velocity, and acceleration	The motion system shall return to the level and lock position with rates less than 4°/sec(angular) or 4 in/sec (linear) and 0.1g
* 3. Reset	Reset the simulator to its initial conditions, record position, velocity, and acceleration	The motion system shall return to the initial condition position with rates less than 4°/sec(angular) or 4 in/sec (linear) and 0.1g
* 5. Isolation	Energize and deenergize the motion system	The flight simulator operation shall not be interrupted in any fashion. Upon deactivation of the motion system, the platform shall return to its level rests at rates less than 4°/sec(angular) or 4 in/sec (linear) at less than 0.1g (linear)or $4°/sec^2$ (angular)
* 6. Manual control	Vary each degree of freedom individually	

APPENDIX C

RECOMMENDATION FOR SPECIFICATION FOR FUNCTIONAL TEST REQUIREMENTS FOR EVALUATING VISUAL DISPLAY SYSTEMS AS USED WITH AIRCRAFT WEAPON SYSTEM TRAINERS AND OPERATIONAL FLIGHT TRAINERS

NAVTRAEQUIPCEN IH-251

RECOMMENDATION FOR SPECIFICATION FOR FUNCTIONAL TEST REQUIREMENTS FOR EVALUATING VISUAL DISPLAY SYSTEMS AS USED WITH AIRCRAFT WEAPON SYSTEM TRAINERS AND OPERATIONAL FLIGHT TRAINERS

1. SCOPE

1.1 This specification contains the requirements to be fulfilled in evaluating the engineering performance of visual display systems as used with Weapon System Trainers (WST) and Operational Flight Trainers (OFT). The requirements consist of tests, test conditions, test configurations, test methods, and tolerances to be met.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on the date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

STANDARDS

MIL-STD-150A	Military Standard - Photographic Lenses
MIL-STD-1241A	Military Standard - Optical Terms and Definitions

SPECIFICATIONS

MIL-T-23991	Training Devices, Military; General Specifications for

(Copies of specifications, standards, publications and drawings required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the Procuring Contracting Officer.)

2.2 Other publications.- The following documents form a part of this specification to the extent specified herein. Unless otherwise stated, the issue in effect on the date of request for proposal shall apply.

ELECTRONIC INDUSTRIES ASSOCIATION

EIA-STD-343	Electrical Performance Standards for High Resolution Monochrome Closed Circuit Television Camera

(Application for copies should be made to Electronic Industries Association, 2001 Eye Street, N.W., Washington, D.C. 20006.)

INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS

IEEE 202, 54 IRE 23, S1	Standards on Television: Methods of Measurement of Aspect Ratio and Geometric Distortion
IEEE 205	Standards on Television: Measurement of Luminance Signal Levels

(Application for copies should be made to the Institute of Electrical and Electronic Engineers, 345 East 47th St., New York, N.Y. 10017.)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

3. REQUIREMENTS

3.1 Application.- The functional test requirements specified herein cover the tests to be performed, the test configurations, the test procedures, and the data which shall be provided. The requirements provide a uniform method for direct comparison of the visual display system with the test criteria data.

3.1.1 Prototype trainers.- Tests conducted on prototype trainers shall consist of all tests specified in 4, and such additional functional tests which may be required in accordance with the detail trainer specification to demonstrate conformance with the reference test criteria.

3.1.2 Production trainers.- For production trainers, tests shall be conducted from 4 to demonstrate conformance to the test results of the prototype trainer. The areas of 4 to be conducted are designated by an asterisk (*). Additional functional testing may be required in accordance with the detail trainer specification.

3.2 Performance of tests.- Tests specified herein shall be conducted by the contractor, subsequent to completion of the quality assurance provisions of MIL-T-23991, and prior to the NAVTRAEQUIPCEN Representative's test and acceptance program. All required tests shall be validated and certified by a Government inspector. This certification shall consist of initialing all original data sheets used in the tests. A copy of these data sheets shall be provided to the Government inspector by the contractor. When changes or recalibration for alignment, equipment failure or adjustment purposes are made during the test programs, such changes shall be recorded on the data sheets. Tests which may have been conducted prior to such adjustments shall be reported unless conclusive proof can be provided that such adjustments have not invalidated the recorded test data up to the time of such adjustments. Upon the successful completion of the tests specified, the trainer shall be made available to the NAVTRAEQUIPCEN Technical Representative for his test and acceptance program.

3.3 Test equipment, programs and instrumentation.- The contractor shall supply all test equipment, programs and instrumentation necessary to conduct the various tests accurately and expeditiously. Test equipment and programs shall include, but not be limited to:

(a) Means for introducing pulse, step, and sinusoidal disturbances of simulated flight control surfaces

(b) Equipment for measuring and recording time

(c) Equipment for real-time data recording of up to 25 variables. Magnetic tape or disc digital data recording are permissable provided the capability to record at the highest iteration rates used is provided. Strip chart recording may be used if a 0.5 percent accuracy is available up to 2 Hz

(d) The capability to command straight and level flight at predetermined flight conditions

(e) The capability to individually and/or collectively freeze roll, pitch, yaw, x, y, and z axes at predetermined locations

(f) Apparatus for measuring luminance (spot photometer), field of view (theodolite), oscilloscope, high and medium resolution charts.

All such equipment and programs shall be checked or calibrated within one month prior to conducting the test program. A list of all test equipment and conversion data shall be included in the Test Procedures and Results Report.

3.4 Reporting of results.- Test results shall be prepared in accordance with the following:

3.4.1 Test procedure format.-

(a) Title of test - including subparagraph number

(b) Purpose - a statement of what the test is intended to accomplish

(c) Test method - a statement indicating how the test is to be performed, including calculations, formulae, and conversion factors required to correlate test results with specified test criteria. When two or more quantitative readings are required simultaneously, the method of utilizing a plotter or data recording and computer printout shall be described

(d) Test equipment and software test aids required - include test points, setup adjustments, and implementing instructions

(e) Initial conditions - include simulator configuration loadings, altitude, speed, gross weight, center of gravity, and setting of controls and the like prior to conducting testing

(f) Additional requirements - discuss personnel required to conduct the testing, potential hazards to personnel performing the testing, and the like

(g) Test procedures - detailed step-by-step procedures are required

(h) Reference aircraft test data to which comparison is being made.

3.4.2 Test data.- The simulator test data shall be presented as curves, tables, or data entries as specified herein.

3.4.3 Reference data.- Simulator test criteria shall be as specified herein.

3.4.4 Tolerances.- All tolerances shall be in accordance with the detail specification; if not specified in the detail specification, the tolerances shall be as specified in the included tables. The simulator performance shall equal the test criteria of 3.4.3 plus or minus the specified tolerances.

3.4.5 Test grouping.- In this specification, tests have been grouped into static or steady state tests and dynamic or transient tests, for convenience. The tests as performed by the contractor shall be sequenced in such a manner as to prevent redundancies of tests and to permit a maximum amount of data acquisition in a minimum of time.

3.5 Revision of test requirements.- Requests for changes (revisions, deviations, or additions), to requirements specified herein, deemed necessary to completely verify the performance of the visual display system shall be presented at the time when the simulation of the aircraft proposed criteria reports are submitted for approval. All such requests shall be substantiated by pertinent facts, in writing, to the Contracting Officer for approval.

4. INSPECTIONS AND TEST PROCEDURES

4.1 Responsibility for inspection.- Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. The Government reserves the right to perform any additional inspections necessary to assure that supplies and services conform to contracted requirements.

4.2 Conditions and configurations.- Conditions and configurations for visual display system testing are shown herein.

4.2.1 Terms and symbols.- Terms used herein and in reporting results shall be in accordance with 6.2.

4.3 Required testing program.- The following areas of visual display system performance shall be tested. Not all areas are applicable to all types of display systems and only those portions which are applicable need be addressed.

4.3.1 System tests.- The following tests (as applicable) shall be performed for all types of visual systems through the entire visual generating and display system.

4.3.1.1 Static accuracy.- The tests of Table I shall be conducted to determine the static accuracy of all visual systems.

4.3.1.2 Dynamic tests.- The tests of Table II shall be conducted to determine the dynamic properties of the visual system. The tests shall be performed for each degree of freedom.

4.3.1.3 Perspective.- The tests, techniques and equipment discussed in Appendix A shall be used to verify the accuracy of the presentation of scene perspective and size.

4.3.1.4 Simulation attributes.- The tests of table III shall be conducted to appraise the simulation attributes of the displayed scene.

4.3.1.5 Interface tests.- The tests of Table IV shall be conducted to verify the interface performance of the visual system.

4.3.2 Display apparatus.- The following tests apply to display and display related apparatus.

4.3.2.1 Display tests.- The tests of table V shall be conducted to verify the display performance.

4.3.2.2 Infinity display optics tests.- The tests of table VI shall be performed to verify the infinity display optics performance.

4.3.2.3 Color displays.- The tests of table VII shall be performed to verify the color performance of the display system.

4.3.2.4 Zoom optics.- The tests of table VIII shall be performed to verify the performance of the zoom optics.

4.3.3 Model board tests.- This section delineates the testing to be performed for model board type image generators.

4.3.3.1 General parameters.- The tests of table IX shall be conducted to verify the general specification parameters.

4.3.4 Servo performance.- The tests of table X shall be conducted to verify servo performance. The tests shall be conducted for all servos of the visual system, i.e., gantry, zoom, model, optical probe, point light, sky-earth projectors, etc.

4.3.5 Television system tests.- The tests of table XI shall be performed to verify performance of the television camera and associated electronic circuitry up to the final display device. The tests shall be performed only if the performance parameters are individually specified in the detail specification.

4.3.5.1 Television camera systems.- The tests of table C12 shall be performed to the television system camera(s) if and only if the performance parameters are individually specified in the detail specification.

4.3.6 Optical systems.- The tests of table C13 shall be performed to individual optical systems to verify their performance. These tests shall be conducted only if the performance parameters are individually specified in the detail specification.

5. PACKAGING. This section is not applicable.

6. NOTES

6.1 Intended use.- This specification is intended to provide the general test requirements for testing synthetic visual display systems and their associated equipment as used with flight simulators and to serve as a basis for the preparation of the test procedures and results reports.

6.2 Definitions.- Definitions used for optical parameters shall be as per MIL-STD-1241. Definitions for television parameters shall be per EIA Standard RS-343.

6.3 Symbols.- The following symbols are referenced in Appendix B, test set-ups, and in table C1.

ANG RES - Angular Resolution

CAM - TV Camera

CCTV - Closed Circuit TV Monitor

CGI - Computer Generated Image

CRT - Cathode Ray Tube

MTF - Modulation Transfer Function

OC - Observer Camera

OSC - Oscilloscope

PHO - Photometer

PROJ - TV Projector

THE - Theodolite

TMB - Terrain Model Board

TS - Test Set-up (see figure 1)

VSA - Video Signal Analysis

WM - Waveform Monitor.

TABLE C1. System tests - static.

TESTS	TECHNIQUE OR EQUIPMENT	TOLERANCE
* 1. Static accuracy	The technique and required equipment are described in Appendix A. The tests shall be applied to the entire system including camera, electronics (or computer generation) display equipment (TV, light valve, etc.) and all optics (zoom, infinity focus, etc.)	
a. Roll excursion		0.5°
b. Pitch excursion		0.5°
c. Yaw excursion		0.5°
d. X excursion		0.5% of command
e. Y excursion		0.5% of command
f. Z excursion		0.5% of command
2. Image size and perspective	"	5% of theoretical

TABLE C2. System tests - Dynamic performance.

TESTS	TECHNIQUE OR EQUIPMENT	TOLERANCE
* 1. Transient response	Monitor step inputs at host computer/visual computer interface. Monitor system response at the display device output (servos or deflection circuits as appropriate). Step amplitudes shall be ± 10 degrees for angular degrees of freedom, and 1000 feet for linear degrees of freedom.	No overshoot allowed greater than 2%, i.e., dumping greater than or equal to .8. The 10% settling time shall be as specified ± 20 msec. (If no 10% settling time is recommended, a 100 msec maximum is suggested.)
2. Steady state time lags	Monitor as described in the transient tests. Excite with ramps of 1.0%, 10% of maximum, and maximum velocity (each DOF).	As specified ± 10%. If not specified, recommend lag to be less than 60 msec.
3. Frequency Response	Monitor as described in the transient tests. Excite with a sinusoid of amplitude 1/4 maximum. Frequency is to vary to 5 Hz.	As specified ± 10% of amplitude (not measured in dB) and phase

TABLE C3. System tests - Simulation attributes.

	TESTS	TECHNIQUE OR EQUIPMENT	TOLERANCE
1.	Scene content	Subjective appraisal of number of edges for CGI systems, subjective evaluation of displayed content for other systems.	At least the number of edges or surfaces specified
* 2.	Scene movement	Subjective appraisal of smoothness of scene movement.	No erratic movement or jitter shall occur in flight.
* 3.	Fresnel Lens Optical Landing System (as applicable)	At a slant range of 6080 ft, place the aircraft "on glide path" (372 ft plus deck height for 3.5° glide slope or 425 ft plus deck height for 4.0° glide slope). Vary the height ± 80 feet (0.75°), the meatball shall display on glide path and then ± 2 ball heights.	1/10 ball, subjective appraisal of FLOLS size as a function of range.
4.	Visual Approach Slope Indicator - VASI - (as applicable)	Position the aircraft on the glide slope. Verify white-red lighting. Position the aircraft 0.75° low on the glide slope; verify red-red lighting. Position the aircraft 0.75° high on the glide slope, verify white-white lighting.	0.1°
5.	Strobe light operation	Subjectively verify correct operation of the strobe.	DNA
* 6.	Atmospheric Effects-clouds, haze, fog, etc.	Subjective appraisal	DNA
7.	Directional lights (as applicable)	Subjective appraisal	DNA
8.	Runway markings (as applicable)	Subjective appraisal	DNA
9.	Approach lights (as applicable)	Subjective appraisal	DNA

TABLE C3. System tests - Simulation attributes. - Continued

	TESTS	TECHNIQUE OR EQUIPMENT	TOLERANCE
10.	Horizon intensity (as applicable)	Subjective appraisal	DNA
11.	Beacon light	Subjective appraisal of color, speed	DNA
12.	Carrier edge lights (as applicable)	Count and subjective appraisal of color and spacing	As specified, DNA
* 13.	Carrier runway center lights (as applicable)	Count, subjective color, spacing appraisal	As specified, DNA
14.	Carrier runway edge lights (as applicable)	Count, subjective color, spacing appraisal	As specified, DNA
15.	Carrier runway athwartships lights (as applicable)	Count, subjective color, spacing appraisal	As specified, DNA
16.	Carrier axial deck bow, athwartship lights (as applicable)	Count, subjective color, spacing appraisal	As specified, DNA
* 17.	Carrier vertical dropline lights (as applicable)	Count, subjective color, spacing appraisal	As specified, DNA
18.	Eyeheight above runway	Subjective appraisal	DNA
19.	Mission playback (as applicable)	Subjective appraisal of presentation for specification compliance	Subjective - DNA
* 20.	Demonstration maneuvers (as applicable)	Subjective appraisal of presentations	DNA
	a. Basic powered flight maneuvers		
	b. Ground taxi		
	c. Takeoff (normal field)		
	d. Takeoff (catapult)		

TABLE C3. System tests - Simulation attributes. - Continued.

TESTS	TECHNIQUE OR EQUIPMENT	TOLERANCE
e. Approach		
f. Waveoff		
g. Landing (normal)		
h. Landing (arrested)		
i. Inflight refueling		
j. Weapons delivery		
k. Air combat maneuvering.		

TABLE C4. System tests - Interface performance.

TESTS	TECHNIQUE OR EQUIPMENT	TOLERANCE
* 1. Freeze	Freeze the simulator. Verify scene content to remain constant.	Subjective - DNA
2. Crash	"Crash" the simulator. Verify crash presentation of specification (freeze, blackout, etc.)	Subjective - DNA
* 3. Reset	Reset the simulator. Verify original scene presentation.	Subjective - DNA
* 4. Isolation	Cycle power off and on for visual system. Verify host simulation to be not interrupted by power transitions.	Subjective - DNA
* 5. Systems synchronization (visual, motion and instrument simulation)	Monitor the host-visual, host-motion and host-instrument interfaces. Record appropriate axes on strip chart. Excite individual axes of flight and compare visual, motion and instrument responses (i.e., motion position, visual display drive and instrument drive signals.) Instrument presentations which are normally delayed are excepted.	Response initiation shall occur within 20 msec of each other.

TABLE C5. System tests - Displays.

		TESTS	TECHNIQUE OR EQUIPMENT	TOLERANCE
*	1.	Luminance, and uniformity of luminance for background and targets.	Spot photometer used to measure luminance at 10° (vertical and horizontal) increments from pilot's nominal eyepoint. TS - C, I, O	Greater than minimum specified value with corner luminance no less than 70% of center luminance.
*	2.	Resolution (on and off axis) horizontal and vertical.	MIL-STD-150 Resolution chart (or programmed version of the same for CGI systems), high and medium contrast charts with focus set at normal setting. Modulation transfer measurement using the observer camera technique or angular resolution using a theodolite may be substituted. TS - A, E, K	On axis, specification minimum; off axis, no less than 80% of the on axis minimum.
	3.	Contrast or contrast ratio	Ratio of maximum luminance to background luminance using spot photometer for all display channels. TS - C, I, O	Greater than minimum specification value.
	4.	Depth of field (not applicable to CGI systems)	MIL-STD-150A resolution chart, determine the resolution at maximum range, close the range until the resolution is 50% of this value. The range difference is defined to be the depth of field.	Greater than the specification minimum.
*	5.	Field of view	Use theodolite from nominal pilot's eyepoint. TS - D, J, P	1°
	6.	Geometric distortion and linearity	Use an EIA linearity chart and the method specified in IEEE 202, 54IRE 23, S1. TS - D, J, P	Grids within 5° of optical axis, 6 arc min deviations; from 5° to 100°, 1% of raster height; greater than 100°, 1°.

TABLE C5. System tests - Displays. - Continued

	TESTS	TECHNIQUE OR EQUIPMENT	TOLERANCE
7.	Display refresh rate	Oscilloscope and photocell	Greater than specification minimum.
8.	Raster burn	Subjective	Not discernible
* 9.	Multiple channel video tracking (as applicable)	Use theodolite to verify linearity of display across boundaries of multiple display screens as viewed within the viewing volume. TS - D, P	Slope changes shall not exceed the greater of 1% or 0.5°.
* 10.	Multiple channel luminance tracking	Spot photometer each 10° on adjacent channels. TS - C, I, O	15%

TABLE C6. Infinity display optics tests.

TESTS	TECHNIQUE OR EQUIPMENT	TOLERANCE
* 1. Viewing volume	Measure X, Y, and Z clear viewing volume	Equal or better than specified
2. Collimation	A dioptrometer shall be used	$\pm$ .02 diopters of specified value
3. Mirror tests (as applicable)		
a. Radium (spherical mirror)	Produce a blur circle: reflected from the entire area of the mirror required to achieve the specified field of view, produced by a 0.5 inch circular stop located normal to and displayed orthogonally from the mirror center of curvature by 1.0 inch	The maximum blur circle dimension composing the image of the stop, on the opposite side of the center of curvature shall be within 10% of the specified value
b. Uniformity of curvature (spherical mirror)	Measure any local variation in the radius of curvature utilizing a ring spherometer sized to measure the sagitta to .0005 inches	The radius variation shall be less than 0.5%
c. Mirror smoothness (spherical)	Locate an edge target (3 X 10 white cardboard with a 0.5 inch black center stripe having sharp edges) anywhere on the focal surface of the mirror. Illuminate the target adequately (50 $\pm$ 5 foot lamberts with ambient lighting less than 10 foot lamberts)	Subjective - An observer located at the approximate center of curvature shall not observe the reflex image of the edge to have any waviness (caused by surface ripples) or feathery raggedness (orange peel effect) or any other irregularity using only the unaided eye.

TABLE C7. Display tests - Color Performance.

	TESTS	TECHNIQUE OR EQUIPMENT	TOLERANCE
*	1. Convergence	Dot and colorbar generator or grid pattern target	In a circular area of diameter .8 times picture height convergence error shall be less than 0.1% of picture height. In a circular area whose diameter is equal to the height, the convergence error shall be less than 0.2%. In the remaining corner area, the error shall be less than 0.5%.
	2. Color capability	Display system capability. Using a colorimeter, evaluate and compare to detail specification requirements	Better than specification value
*	3. Color tracking (as applicable)	Colorimeter evaluation of color tracking (from screen to screen for multiple screen systems or throughout a single screen for large displays	DNA

TABLE C8. Display tests - Zoom optics.

TESTS	TECHNIQUE OR EQUIPMENT	TOLERANCE
1. Magnification	Material and techniques are described in Appendix A	5%
* 2. Optical Axis Shift	Place a paint target on the optical axis with the zoom optics at the minimum zoom configuration. Activate the zoom to the maximum zoom configuration, monitor the change in position of the target.	Target shift shall not exceed 5 arc minutes

TABLE C9. Model board tests - General Parameters

TESTS	TECHNIQUE OR EQUIPMENT	TOLERANCE
1. Texture	Subjective evaluation of final viewed scene for appropriateness of scene texture and seams	DNA
2. Color	Subjective evaluation of final viewed scene for appropriateness of natural color presentation	DNA
3. Illumination	Measure illumination of the model board every 8 feet in X and Y	Better than specified minimum
4. Dimensions (overall)	Measure model board overall dimensions	0.5 feet

TABLE C10. Servo Tests.

TESTS	TECHNIQUE OR EQUIPMENT	TOLERANCE
*1. Excursion limits	Command full excursion, monitor feedback device	Equal to or greater than specified
2. Velocity limits	Step input	Equal to or greater than specified
3. Acceleration limits	Step input or sinusoidal input	Equal to or greater than specified
*4. Static accuracy (positional)	Command position, monitor feedback device (if one is used) or measure response. Command to include 1/4, 1/2, 3/4 maximum.	.15% of command
5. Repeatability	Command same position approaching the position from either side	.02% of initial command
6. Dynamic accuracy (velocity tracking)	Command ramp inputs of 1/100 maximum and 1/2 maximum rate. Monitor positional and rate feedback devices	Response amplitude shall be within 10% of command. Velocity fluctuations shall be less than 2% of command
*7. Transient response	Command step input of the lesser of 1/10 maximum excursion or 30°. Use velocity step for velocity servos	Damping, .1 of specified value; natural frequency, .2 Hz of specified. If not specified, recommend .7 $\pm$ 1 damping, 25 $\pm$ 3 radians per second frequency
8. Frequency response	Obtain Bode plots of amplitude and phase	0 to 1 Hz, 2db, 10° 1 Hz to 2 Hz, 4db, 20° 2 Hz to 5 Hz, 8db, 40°
9. Reset speed	Activate reset from various origins. Monitor speed	10% of specified. If not specified, 10 inches/sec

TABLE C11. Television system tests (to be performed only if specified in the detail specification)

TESTS	TECHNIQUE OR EQUIPMENT	TOLERANCE/COMMENT
1. Bandwidth	Necessary bandwidth = 1.5 N/T where N/T = Total picture elements (Black and White) transmitted per sec = number of lines forming each image x elements per line x pictures transmitted per second, Bandwidth to be measured at 3 decibels down from peak	Specification value ± 5 MHz. If not specified, recommend 1.5 N/T at ± 3dB down
2. Gamma		Within 10% of specified or unity if not specified
3. Signal to noise	Ratio of RMS signal to RMS noise	Specification value ± 2dB. If not specified, recommend 40 dB
4. Resolution	MIL-STD-150 resolution chart, high and medium contrast charts with focus set at normal setting. Angular resolution using a theodolite or MTF may be substituted.	Greater than specified. If not specified, recommend 700 TV lines minimum in center, 550 in corners.

TABLE C12. Television camera tests (performed only if test areas are specified in the detail specification).

TESTS	TECHNIQUE OR EQUIPMENT	TOLERANCE/COMMENT
1. Geometric Distortion	Specified in IEEE 202, IRE 23.S1, Standards on television: Methods of measurement of Aspect Distortion	2% of picture height
2. Resolution	Specified in IEEE 208, 60 IRE 23.S2, Standards on Video Techniques: Measurement of Resolution of Camera Systems	Per table I of EIA Standard RS-343-A, Electrical Performance Standards for High Resolution Monochrome Closed Circuit Television Camera
3. Gray Scale	Per EIA Standard RS-343-A	All ten steps of the EIA resolution chart shall be visible
4. Luminance	Per IEEE Std 205	Detail specification values $\pm$ 5%

TABLE C13. Optical system tests (only as specified in the detail specification).

TESTS	TECHNIQUE OR EQUIPMENT	TOLERANCE/COMMENT
1. Image size	All tests of this section to be performed per MIL-STD-150A for all lens systems used in the display system	All tolerances required for this section are to be supplied in the Detail Specification
2. Entrance pupil size and position		
3. Depth of field		
4. Focal length		

STATIC AND PERSPECTIVE ACCURACY TESTING

1. Referring to the test configuration of Figure C14, select a rectangular viewing target such as a landing field, carrier deck, or artifically introduced target such as a 3 X 5 card (model board systems) or a programmed rectangle, such that all the designated angles remain in the field of view provided by the visual system under test.

2. The angles shown in Figure C14 are defined as follows:

$$\theta_1 = \mathrm{Tan}^{-1} \frac{h_1}{(L + X_1)} \qquad \psi_1 = \mathrm{Tan}^{-1} \frac{w/2}{\sqrt{(L + X_1^2) + h_1^2}}$$

$$\theta_2 = \mathrm{Tan}^{-1} \frac{h_1}{X_1} \qquad \psi_2 = \mathrm{Tan}^{-1} \frac{w/2}{\sqrt{X_1^2 + h_1^2}}$$

$$\theta_3 = \mathrm{Tan}^{-1} \frac{h_2}{(L + X_2)} \qquad \psi_3 = \mathrm{Tan}^{-1} \frac{w/2}{\sqrt{(L + X_2\ ) + h_2^2}}$$

$$\theta_4 = \mathrm{Tan}^{-1} \frac{h_1}{X_1} \qquad \psi_4 = \mathrm{Tan}^{-1} \frac{w/2}{\sqrt{X_2^2 + h_2^2}}$$

3. Verify the static and perspective accuracy of the visual presentation by positioning the simulated aircraft to the locations of table C14 and determining the pitch, width, and presentations required.

TABLE C14. Static and Perspective Accuracy Test Conditions.

Aircraft Location	Position X	Position Y	Item Viewed	Apparent Pitch Angle	Apparent Width	Apparent Roll Angle	Comments
1.	X_1	0	Far target edge	θ_1	$2\psi_1$	0°	See Figure A2
1.	X_1	0	Near target edge	θ_2	$2\psi_2$	0°	"
2.	X_2	0	Far target edge	θ_3	$2\psi_3$	0°	"
2.	X_2	0	Near target edge	θ_4	$2\psi_4$	0°	"
3.	X_2	w/2	Target RH side	θ_3, θ_4	$2\psi_3$, $2\psi_4$	0°	RH side shall follow display center line. See Figure A3
2.	X_2	0	Horizon, Far and Near Target edges	NA	NA	30°,45°,60°	A/C Roll to be ± 30°, 45°, 60°. Horizon to be ± 30°, 45°, 60°. See Figure A4
2.	X_2	0	Target near right corner	NA	NA	NA	Rotate A/C about the body axes θ_4 about Y, ψ_4 about Z. Target near right corner shall appear on display center line.

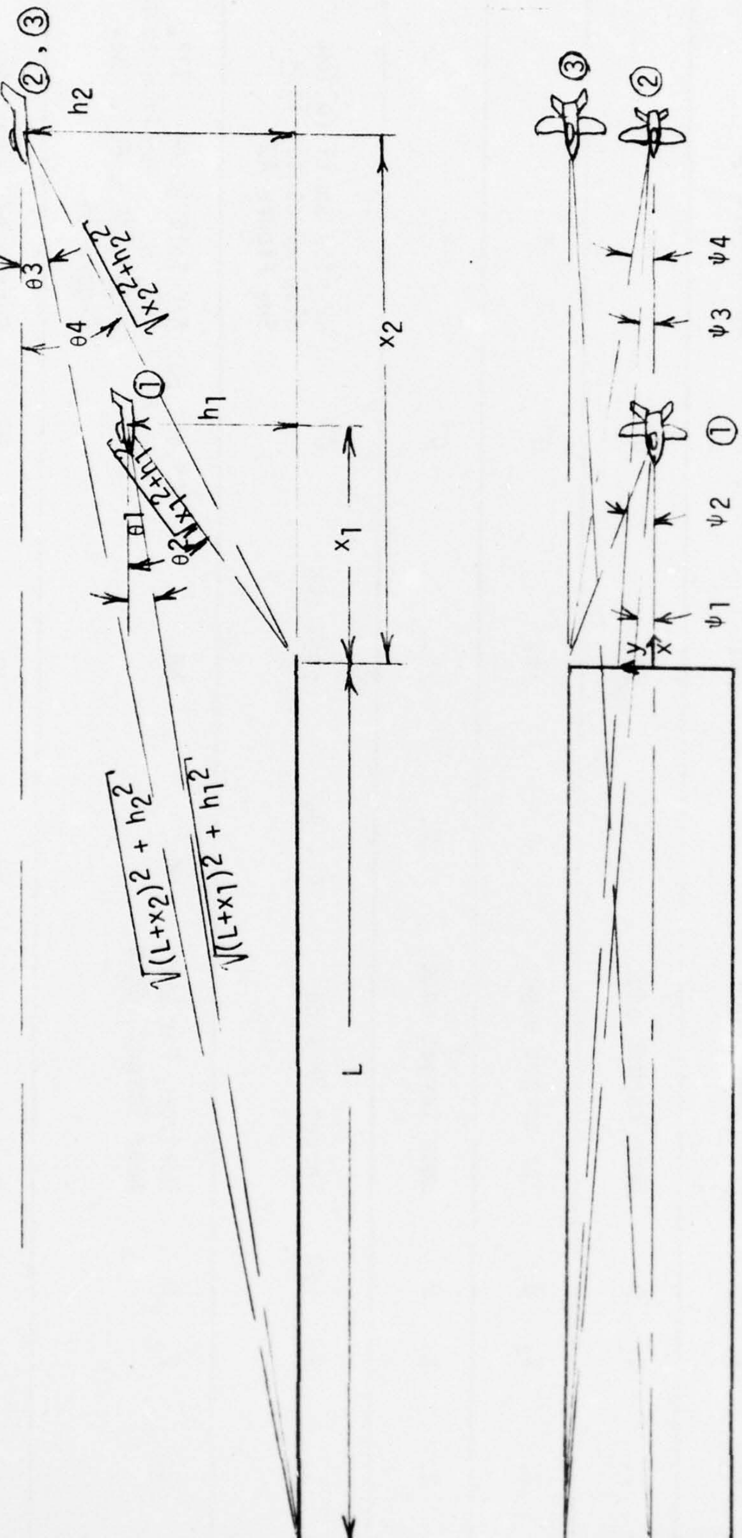

FIGURE C1. STATIC AND PERSPECTIVE ACCURACY TESTING CONFIGURATION

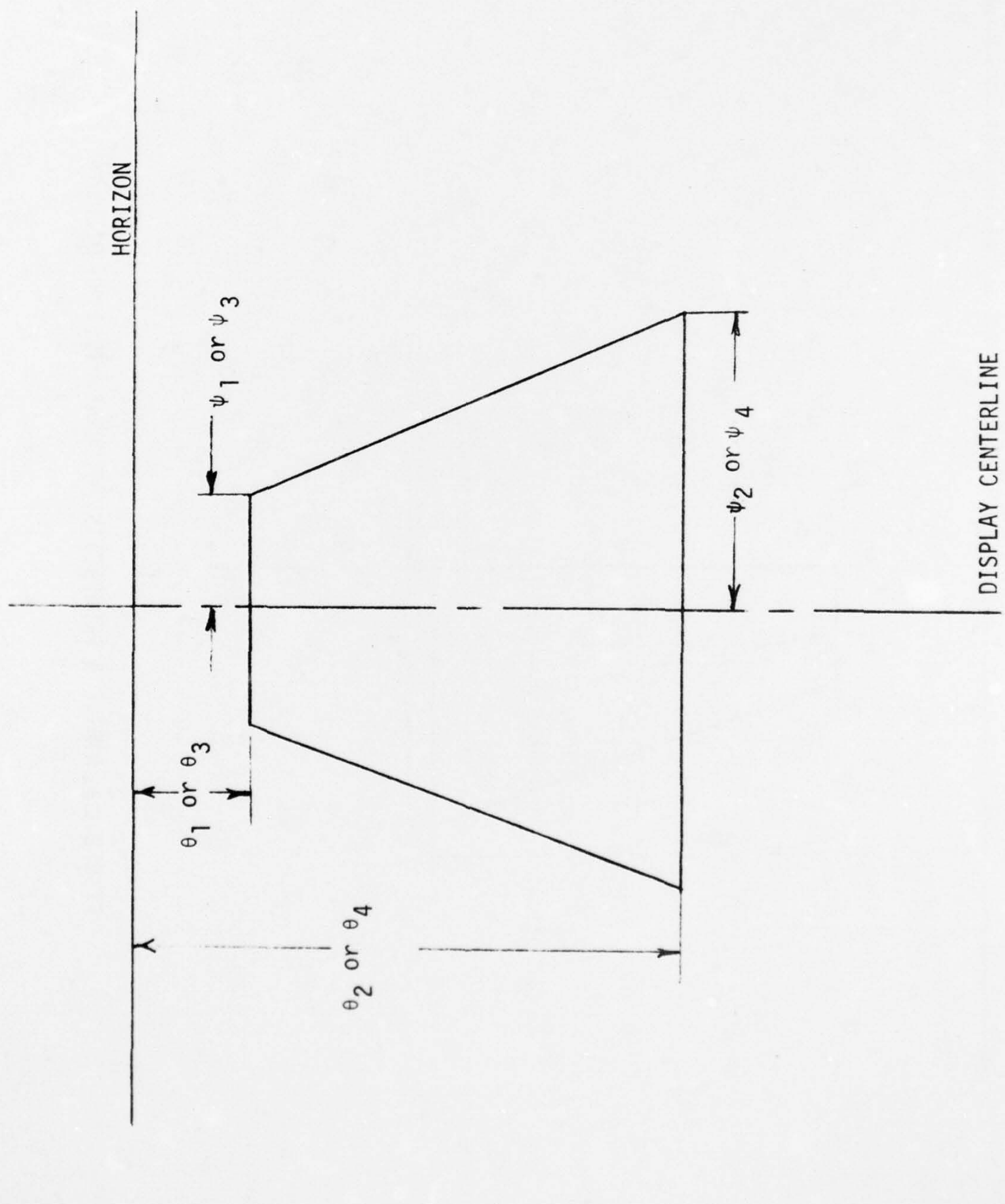

FIGURE C2. STATIC & PERSPECTIVE ACCURACY TESTING DISPLAY

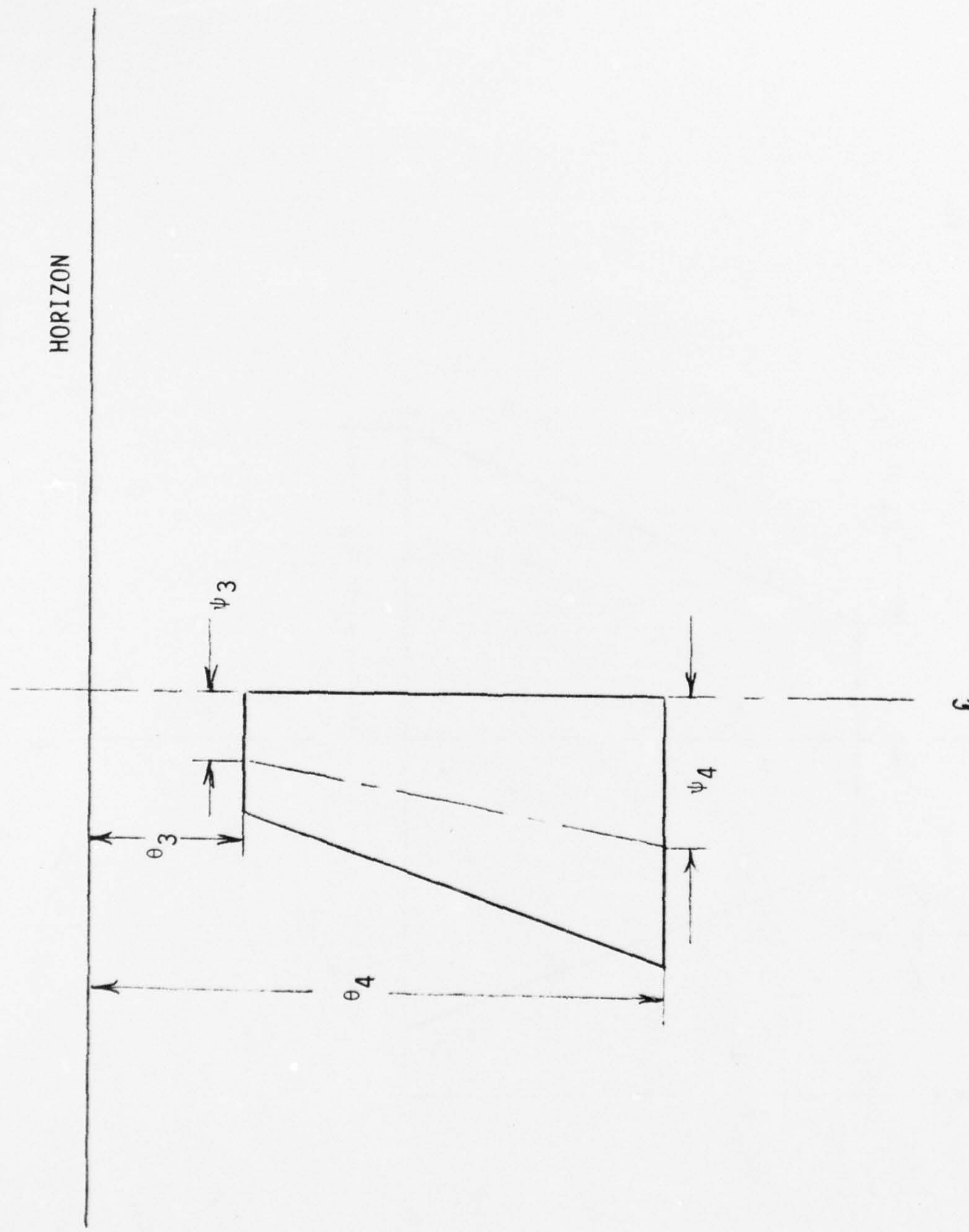

FIGURE C3. STATIC & PERSPECTIVE ACCURACY TESTING DISPLAY

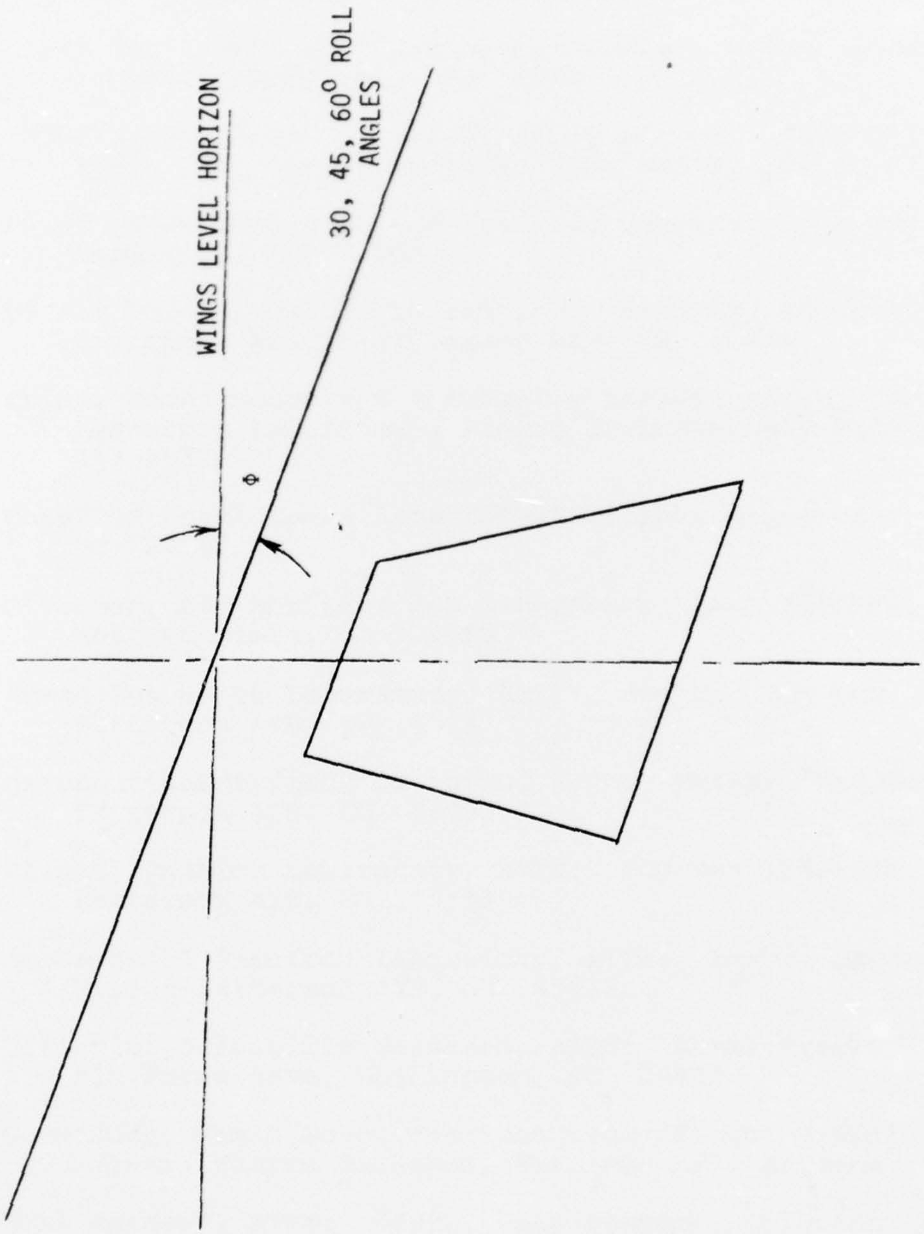

FIGURE C4. STATIC & PERSPECTIVE ACCURACY TESTING DISPLAY

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